Assessment of El Niño-Associated Risks: The Step-Wise Process

18 June 2016
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References
1. Introduction

The combination of global, regional and local climate drivers causes variations in the climate over space and time. The El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and North Atlantic Oscillation (NAO) are few of the known dominant global climate drivers. Among the global climate drivers, ENSO accounts for more than 20-30% global climate variability (Anderson and Strahler, 2008) and therefore ENSO is considered as one of the key climate drivers for predicting climate variability over different parts of world.

The El Niño Southern Oscillation (ENSO) is a periodic climatic phenomenon with 3-7 years of cycle. ENSO’s warm phase is referred as El Niño and its cold phase is referred as La Nina. El Niño refers to warming of the central and eastern Pacific or the entire Pacific basin, which affects trade winds, in turn affecting the atmosphere and weather patterns. The reverse cycle, called La Nina, involves cooling of the central and eastern Pacific Ocean, which is the strengthening of the normal conditions in the Pacific. ENSO’s phases affects the weather system in various ways and thereby causing biophysical and socioeconomic impacts. Especially, during the El Niño years, the change in weather patterns poses a huge socio-economic threat across the Asia-Pacific region. The 1997-1998 El Niño, for example, caused 23,000 fatalities from natural disasters, increased poverty rates by about 15 percent in many countries, and cost governments up to USD 45 billion from impacts of severe droughts, storms, and other related hazards (World Bank, 2015). The 2015-2016 El Niño triggered weather extremes, from severe drought in South and Southeast Asia to intense rainfall in the Pacific. UNOCHA (2016) interim preliminary estimates highlighted that the event has affected 60 million people globally.

El Niño impacts on weather systems over Asia-Pacific have been predominantly interpreted as wet (flood) or dry (drought) conditions. However El Niño impacts on weather patterns and its associated biophysical and socioeconomic consequences are complex and highly variable over space and time due to various factors. The existing methodologies to assess the impacts of varying weather and climate characteristics on bio-physical and societal systems are inadequate to capture these complexities. Therefore it is critical to address the existing gaps by evolving a methodology to interpret, translate and communicate El Niño associated risks. In addition, El Niño is the main driver for seasonal prediction and its effects on ocean and the atmosphere lend better confidence to these predictions. Hence the lag time between El Niño onset and its impact on weather patterns offers opportunities to assess socioeconomic impacts, as well as management strategies.

A draft methodology is prepared and discussed with stakeholders from Asia-Pacific countries during the regional consultative workshop 7-9 June 2016 held at Bangkok Thailand, organized by United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and United Nations Development Programme (UNDP). The feedback on the methodology from the participants are incorporated in this updated methodology document.

The step-wise risk assessment process is shown in Figure 1.1, and each step is elaborated from chapters 2 to 9. This methodology provides a guideline to estimate
the impacts to aid decision makers in preparing response option. However, the response options or strategies for the assessed impacts are not dealt in this methodology.

Figure 1.1 Steps involved in the assessment of El Niño-associated risks

“Assumption in Analogue approach – The forecasted El Niño episode that are somewhat similar to the past El Niño episode are likely to cause the similar impacts on weather system. In addition, the sensitivity of sectors to the impacts on weather are likely to experience similar impacts, however it varies based on the capacity and other factors.”

As the first step, the El Niño forecasts from the global and regional centers can be reviewed and evaluated. Based on the probability of El Niño occurrence, the El Niño forecast could be considered for informed decision making process with a confidence level (Step-1). By understanding the different flavors of El Niño (Step-2), the characteristics of the forecasted El Niño episode could be matched with the past El Niño episodes that resembles similar characteristics. The impacts on weather patterns during the past El Niño episodes could be considered as an indication for the forecasted El Niño year, as the weather patterns are likely to reoccur. Further, characterizing the weather impacts at country level (Step-3) and also at regional scale for different seasons (Step-4) would help assessing the El Niño impact on regional and local weather patterns. Once the spatiotemporal variation of El Niño impacts are understood on the weather patterns, further, the manifestation on the bio-physical (Step-5) and socioeconomic impacts (Step-6) from the past experiences can be evaluated. Depending on the socioeconomic conditions, the recovery process takes time even though the next season is normal, and this has to be evaluated carefully (Step-7). Responding and adapting to El Niño risks requires significant step-wise assessment of El Niño associated risk, estimating the potential impacts, management strategies and effective risk communication. Not only El Niño forecast matters, but
also participation from decision makers of various sectors – disaster management, public health, agriculture, water resources, etc. are required to cooperate and communicate (Step-8) to ensure that resources are shared, information is up to date and accurate and that response is equitable for all stakeholders. (IRI, 2016).

The vulnerability to El Niño risk depends on its unique sociopolitical and economic characteristics (IRI, 2016). If a country has well developed infrastructure, highly organized emergency management, irrigated agriculture, and a well-informed population will be well equipped to respond to fires, floods, droughts or crop failures, even if it is in a climate-vulnerable region, the country will have lesser risk. At the same time, if a country with fewer resources may be more vulnerable to climate risks, even if it is in an area that typically sees fewer climate hazards. Therefore, assessing - potential effects of El Niño requires understanding the geography, vulnerability and culture of a given area.

**Knowing the boundaries**

“The step-wise risk assessment of El Niño risks requires cross-sectoral cooperation, as various steps in the assessment requires various domain/sectoral expertise such as meteorology, agriculture, water resource, socio-economics, public health, food security, disaster risk management, planning, infrastructure and risk communication. Ideally all these expertise are not in one place in countries. Hence, the risk assessment process has to be carried at countries by evolving a cross-sectoral cooperation and also knowing their boundaries in their process for better outcomes”
2. Review of Existing Global El Niño Forecasts (Step -1)

The aim of step-1 is to review the ENSO forecast from various sources to know the probability of occurrences of El Niño conditions with a confidence level for informed decision making anticipating the potential impacts.

The ENSO forecast is available for various Niño regions: Niño 1, Niño 2, Niño 3, Niño 3.4, and Niño 4 (Figure 2.1). The warming over Niño 3, 3.4 and 4 regions has varying impact across Asia-Pacific. Typically, Niño 3.4 is considered for evaluating El Niño conditions in Asia-Pacific. The SST anomaly over these regions are forecasted by various global centers and there are standard thresholds available to characterize the SST anomalies: El Niño (> +0.5°C), Normal (-0.5° to +0.5°C) and La Nina (< -0.5°C).

Figure 2.1: Niño regions in the Pacific basin

The ENSO forecasts are available from various global and regional centers (Table-2.1). The forecast products are available as texts (summaries, outlooks) and graphics (graphs, maps).

Table 2.1 El Niño forecast products

<table>
<thead>
<tr>
<th>El Niño forecasts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APEC Climate Center (APCC)</td>
<td>ENSO outlook is published for six months duration based on the six individual models and a composite model. <a href="http://www.apcc21.org/set/enso.do?lang=en">http://www.apcc21.org/set/enso.do?lang=en</a></td>
</tr>
<tr>
<td>International Research Institute for Climate and Society (IRI) model based</td>
<td>The IRI model based probabilistic ENSO forecast is published at monthly frequency for a year period, derived from 15 dynamical models and 8 statistical models.</td>
</tr>
</tbody>
</table>
### ENSO forecast

<table>
<thead>
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<tbody>
<tr>
<td>ECMWF Niño plumes long range forecast summarizes the SST conditions over the various ENSO domains in the Pacific basin from its 51 forecast ensemble members. The product is published for every month for a year period. <a href="http://www.ecmwf.int/en/forecasts/charts/seasonal/Niino-plumes-public-charts-long-range-forecast">http://www.ecmwf.int/en/forecasts/charts/seasonal/Niino-plumes-public-charts-long-range-forecast</a></td>
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<tbody>
<tr>
<td>POAMA outlooks are updated every 15 days that summarizes a range of possible developments in sea surface temperature (SST) in the equatorial Pacific Ocean (NINO regions) for up to nine months ahead from different ensemble members of the dynamic climate system model in the POAMA model. <a href="http://www.ecmwf.int/en/forecasts/charts/seasonal/Niino-plumes-public-charts-long-range-forecast">http://www.ecmwf.int/en/forecasts/charts/seasonal/Niino-plumes-public-charts-long-range-forecast</a></td>
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<tbody>
<tr>
<td>WMO update is an advisory issued at a timely fashion (as and when there is a need for update from the previous advisory) that is based on assessment of various global ENSO products and climate outlooks. <a href="http://www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html">http://www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html</a></td>
<td></td>
</tr>
</tbody>
</table>

The IRI/Climate Prediction Center (CPC) probabilistic ENSO forecast (Figure-2.2) is regularly updated (every 15 days) and available from IRI’s website [http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/](http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/). The graph shows the probability of El Niño during every three months from April –June 2016 to Dec 2016-Feb 2017 (as of 19 May 2016). The forecast indicates the persisting El Niño during May 2016 will cease down from June 2016. The probability level gives a chance of occurrences of the forecasted condition. Higher the probability higher the likely ENSO conditions and thereby higher confidence in considering the forecast for informed decision making.

**Figure 2.2.** IRI/CPC model based probabilistic ENSO forecast
IRI also releases text summaries of ENSO forecast. Here is an example “During mid-May 2016 the positive tropical Pacific SST anomaly was quickly weakening, now indicating only a weak El Niño. The atmospheric variables continue to support the El Niño pattern, but at much reduced strength. This includes only a mildly weakened Walker circulation and excess rainfall in the central tropical Pacific, failing to extend eastward as it did in previous months. Most ENSO prediction models indicate a return to neutral by the end of May, with likely development of La Niña (of unknown strength) by fall – IRI 19 May 2016”

The forecasted SST anomalies over Niño 4 region from ECMWF multi-model ensemble is shown in Figure 2.3. The agreement of more number of ensembles symbolizes more chances of occurrence of the forecasted conditions.

Figure 2.3 ECMWF Niño 4 SST anomaly during Nov 2015 to Jan 2016

Australian Bureau of Meteorology releases ENSO outlook both in text and graphical forms. The texts summarizes the interpretation of SST anomalies and also other climate driver such as Indian Ocean Dipole as shown in Figure 2.4

Figure 2.4 Climate Model Summary for June to October 2016
From the ESCAP and RIMES advisory note on Impact outlook and policy implications, the El Niño 2015-16 forecast summary is presented below for demonstration purpose.

**El Niño 2015-16 forecast summary – as of 15 October 2015**

<table>
<thead>
<tr>
<th>International Prediction Centers</th>
<th>Forecast Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Meteorological Organization (WMO), 1 September 2015</td>
<td>A mature and strong El Niño is now present in the tropical Pacific Ocean. The majority of international climate outlook models suggest that the 2015-16 El Niño is likely to strengthen further before the end of the year.</td>
</tr>
<tr>
<td>International Research Institute for Climate and Society (IRI), October 8, 2015</td>
<td>The Strong El Niño conditions persisting during the September-November 2015 season is likely to further strengthen and could last until April 2016.</td>
</tr>
<tr>
<td>Bureau of Meteorology (BOM), Australia, 29 September 2015</td>
<td>The current strong El Niño conditions is likely to persist into early 2016.</td>
</tr>
<tr>
<td>APEC Climate Center, October 2015</td>
<td>The persisting strong El Niño conditions is expected to slightly enhance and persist into 2016 suggesting further strengthening of the El Niño, with the peak of Niño3.4 index being expected during the last quarter of 2015.</td>
</tr>
</tbody>
</table>

*Source: ESCAP and RIMES, 2014b*
3. El Niño Characterization (Step-2)

The aim of step-2 is to understand different characteristics of the past El Niño episodes. So that the impacts of the past El Niño episodes could be inferred for the forecasted El Niño episode that resembles somewhat similar characteristics in the past.

Every El Niño event is unique and having a varying impacts in the weather patterns over Asia-Pacific, hence a careful interpretation is required in characterizing the El Niño episode and also while generating potential impact outlooks. For instance, the varying characteristics (type, magnitude, onset timing, and duration) of El Niño from 1981-2016 are tabulated in Table-3.1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Type</th>
<th>Magnitude</th>
<th>Onset</th>
<th>End</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-88</td>
<td>M</td>
<td>Moderate</td>
<td>Sep 1986</td>
<td>Feb 1988</td>
<td>18</td>
</tr>
<tr>
<td>2002-03</td>
<td>C</td>
<td>Moderate</td>
<td>Jun 2002</td>
<td>Mar 2003</td>
<td>10</td>
</tr>
<tr>
<td>2006-07</td>
<td>C</td>
<td>Weak</td>
<td>Sep 2006</td>
<td>Jan 2007</td>
<td>5</td>
</tr>
<tr>
<td>2009-10</td>
<td>C</td>
<td>Moderate</td>
<td>Jul 2009</td>
<td>Apr 2010</td>
<td>10</td>
</tr>
<tr>
<td>2014-16</td>
<td>M</td>
<td>Strong</td>
<td>Nov 2014</td>
<td>May 2016</td>
<td>19</td>
</tr>
</tbody>
</table>

M – Modoki El Niño, C-Canonical El Niño

Darker shade represent spring type (Apr-June) and lighter shade represent summer-fall type (Jul-Nov)

The varying characteristics of El Niño are demonstrated with relevant case examples.

**Onset:** The onset of El Niño is defined based on the warm sea surface temperature anomalies exceeding the thresholds (>0.5°C) for over three months period in the central/equatorial over the Pacific Ocean. The onset typically happens during the summer season April to June, which will have impacts over the wide geographical domain, as these El Niño events occurs before the beginning of wet season in Asia-Pacific region (e.g. 1982-83, 1991-92). However, El Niño events occurs during/after August are likely to cause impacts only over the regions which has wet season during the Nov-Apr (e.g. 1994-95, 2004-05). As a rule of thumb, the El Niño onset happening after the cessation of wet season are likely to cause less negative impacts.

**Duration:** Once the El Niño onset begins, the duration of El Niño lasts for 5-19 months. The duration is highly variable from event to event. In the last three decades, 1986-88 El Niño lasted for 19 months starting from August 1986 to till April 1988, 1991-92 El Niño event lasted for 14 months starting from April 1991 to June 1992. The recent 2014-16 El Niño like conditions have been prevailing since November 2014 and expected to continue till May 2016. 1986-88 and 1991-92 El Niño events
are of moderate intensity that caused severe impacts compared to 1997-98 El Niño that had strongest intensity but lasted for lesser duration.

**Magnitude:** The magnitude is defined based on how intense the warming happens in the Pacific Ocean. Though there are various indices available to categorize the magnitude, the four categories of El Niño magnitude based on the Ocean Niño Index (an index derived based on sea surface temperature anomaly in the Pacific) are widely used: Weak (0.5 to 0.9°C), Moderate (1.0 to 1.4°C), Strong (1.5 to 1.9°C) and Very Strong (≥ 2.0°C). The impacts of El Niño varies based on the magnitude of these El Niño types (Null 2016). The magnitude alone is not enough to determine the impacts, as the impacts are combination of various characteristics of El Niño. The impacts of the strongest El Niño event 1997-98 was very low in India compared to moderate El Niño episode 1991-92.

**Spatial extent of warming in the Pacific Ocean:** Based on the region of warming happens in the Pacific Ocean, El Niño is classified as Canonical El Niño (warm anomalies in the eastern Pacific, see Figure 3.1) and Modoki El Niño (warm anomalies in the central Pacific, see Figure 3.2). Recently, a basin wide tropical Pacific (TP) warming is seen during the years 2009 and 2014 (Jadhav et al. 2015). Typically these differences in warming occurs due to pre-onset conditions of ocean and atmospheric wind anomalies. These three different El Niño episodes have differential impact in weather patterns over the different regions of Asia-Pacific. The El Niño episodes with warming in the central Pacific tend have stronger impacts in the Asia-Pacific region (1982-83, 1986-88, 1997-98)

![Figure 3.1 Warming over the Eastern Pacific regions during the El Niño years 1991-92, 1994-95, 2002-03, 2006-07, 2009-10.](image)

![Figure 3.2 Warming over the Central Pacific regions during the El Niño years 1982-83, 1986-88, 1997-98.](image)
Evolution and progression of El Niño episode: Usually El Niño cycle has a phased evolution as follows, precursor stage - onset phase - mature phase - peak phase - decaying phase. Some event follows this gradual phase evolution and few events may not follow this phase evolutions. For example, 1997-98 El Niño had a rapid onset and decayed fast as well. Horil and Hanawa (2004) studied the relationship between the timing of El Niño onset and the subsequent evolution from 1871 to 2000. They identified that El Niño events which has onset from April to June (spring type) grow greater in magnitude and take the mature phase around a boreal winter and the evolution is relatively regular and the El Niño events which has onset from July to October (summer-fall type) are relatively weaker in magnitude, and have rather irregular aspects (Figure 3.3).

![SST anomalies during a strong El Niño (1997-98) and weak El Niño (2004-05)](image)

Antecedent warming and manifestation of El Niño: Though the occurrence of El Niño follows a cycle of 3-7 years, there were more number of El Niño events in the decades of 1980’s and 1990’s, as warming conditions persisted in most of the years during these decades. The El Niño associated drought events during this period resulted in severe societal impacts. The 2015-16 El Niño episode is followed by the 2014-2015 El Niño like condition, hence it was expected that the impacts are likely to be aggravated by the antecedent warming condition.

Influence of regional/local climate drivers: The climate drivers such as Indian Ocean Dipole and Madden Julian Oscillation has a greater role in causing rainfall variability (at seasonal and sub-seasonal time scale) in the regional climate, especially in the Asian monsoon regime, through its atmospheric connections. Depending on the status of these climate drivers during El Niño years, the impacts of El Niño could be aggravated or reduced. For example, India had favorable rainy condition during the strong El Niño year 1997-98 because of local synoptic systems. Similarly the monsoon system governing a region heavily modulates the impacts over a region. For instance, the influence of El Niño in developing phase on monsoon systems over Indonesia are more pronounced on delayed onset of monsoon rainfall and not during its progression. The influence of El Niño in decaying phase have a discernible pattern. The gradient of enhancement or suppressed weather patterns are depending on its...
climatological zones that is defined by topographical features (maritime and orographic effects).

**Hazard profile:** The El Niño impacts are highly linked to the hazard profile and climatological zones of a region. The key reason is that the suppressed rainfall conditions in wet zones experiencing heavy flooding every year could be favorable for those regions (e.g. Northeastern India), whereas not in the dry or rainfall dependent regions (e.g. central India). Similarly the enhanced rainfall conditions in the wet zones could aggravate flooding (e.g. coastal districts of southeastern peninsular India), whereas it could provide favorable for the dry and arid environment (e.g. interior districts of southeastern peninsular India). The enhanced cyclone frequencies caused by El Niño are likely to cause negative impacts over the regions exposed to higher cyclonic risk than the regions with less cyclonic risk.

**Identification of analogues based on forecasts**

Though no two El Niño’s impacts are identical, but the past El Niño associated risk patterns could provide a guidance to anticipate and manage El Niño associated risks. The climate phenomena are recurring with different frequencies, hence spatial and temporal analogue methods are widely used to predict the characteristics and its impact of El Niño from the past. The analogue scenarios of El Niño could be constructed based on location of the maximum SST anomaly and strength (Magnitude of the SST anomaly), months of onset (either before May or after August) expected duration (from onset to demise duration) and antecedent conditions (El Niño follows a La Nina or Neutral or periods of consistent warming). For example, 2015-16 El Niño event is very strong El Niño in the recent history that resembled most of the characteristics of El Niño years 1982-83, 1972-73, and 1997-98.

**Building a catalogue of El Niño impacts on weather parameters in the past**

The impacts of El Niño on weather parameters (rainfall, temperature, cyclone frequencies) during different El Niño years has to be constructed in order to use as an analogue for the future El Niño episodes that resemble the characteristics of El Niño occurred in the past. A case of rainfall deviation maps during El Niño years is shown below to understand the rainfall variability during the selected El Niño episodes in the past (Figure 3.4-3.8). However, the rainfall departure maps has to be prepared for multiple seasons and also for every El Niño episode to have a comprehensive catalogue. The composites can give a general indication of how rainfall departs from the normal during the selected few El Niño episodes (Figure 3.9). However the consistency of the deviations has to be dealt with probabilistic approach, which is explained in Chapters 4 and 5. The rainfall deviation for individual years and also composite maps can be prepared using the ESRL NOAA online tool available at http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl
Figure 3.4 Rainfall deviation during the El Niño year 1987-88 from normal (1981-2010) (a) Jun-Sep and (b) Oct-Dec
Figure 3.5 Rainfall deviation during the El Niño year 1994-95 from normal (1981-2010) (a) Jun-Sep and (b) Oct-Dec
Figure 3.6 Rainfall deviation during the El Niño year 1997-98 from normal (1981-2010) - (a) Jun-Sep and (b) Oct-Dec
Figure 3.7 Rainfall deviation during the El Niño year 2004-05 from normal (1981-2010) - (a) Jun-Sep and (b) Oct-Dec
Figure 3.8 Rainfall deviation during the El Niño year 2009-10 from normal (1981-2010)
Figure 3.9 Rainfall deviation during the El Niño year 1997-98, 1994-95, 1997-98, 2004-2005, 2009-10 from normal (1981-2010) - (a) Jun-Sep and (b) Oct-Dec
4. Assessment of Changes in Probability of Extremes in Asia-Pacific Region (Step-3)

The aim of step-3 is to assess the impact of El Niño episode on rainfall, temperature and cyclone frequencies at national/country level.

The manifestation of El Niño at different stages have differential impacts on global weather patterns, especially on temperature, precipitation and cyclone frequencies have been widely documented. The El Niño impacts are not consistent all the times and exhibits huge variation over space and time.

The probable nature of the El Niño on understanding the extremes in Asia-Pacific region is described in Box 4.1

**Box 4.1 El Niño impacts has to be treated probabilistically and not with absolute certainty.**

El Niño and La Niña are such powerful forces that they can shift seasonal temperature and precipitation patterns around the globe. These shifts, known as teleconnections, occur via the effects of tropical sea-surface temperatures on the upper atmosphere. When different parts of the tropical ocean warm and cool and the pressure gradients shift, the atmospheric wind patterns also shift to alter precipitation patterns. The shift in location and intensity of tropical rainfall patterns results in shifts in the location and intensity of the jet stream and storm tracks, tropical cyclones and more. Because each El Niño and La Niña event has unique characteristics of timing, intensity and specific pattern changes, such shifts are never exactly the same during every El Niño and La Niña event. In addition, the atmospheric effects due to changes in sea-surface temperatures are responsible for only part of the regional climate observed; chaotic fluctuations within the atmosphere and sea surface temperatures in other areas of the globe also influence the weather and climate we experience. Because of this, anticipated ENSO impacts in seasonal forecasts are treated probabilistically and not with absolute certainty.

Source: IRI, 2016

In this step, the evaluation of impacts will be carried out at national level in order to provide information to the decision makers at national and regional level for planning strategies to manage the impacts.

The temperature and precipitation characteristics during El Niño years are shown in Figure 4.1. The cyclone frequencies in the Pacific Islands are generally interpreted as increased during the El Niño years.
The changes in weather patterns during various stages of similar El Niño episodes in the past could help estimating the probability of these shifting extreme patterns at regional or country level for a forecasted El Niño episode to get a broader picture before going further down at finer spatial and temporal scale for assessment. In general, the El Niño episodes are associated with suppressed rainfall condition over Southeast Asia. Many studies documented the prominent effect over Australia, Indonesia, and India. Even though India is considered to experience drought like condition during El Niño years, it varies for every El Niño episodes. Hence, representing the impacts based on the probability over different El Niño years would give confidence on taking decisions based on forecast. The consistency of the El Niño impacts on Indian summer monsoon and North East monsoon are discussed below.
The Indian summer monsoon rainfall (June to September months) during 1871-2002 along with the ENSO condition is shown in Figure 4.2. The analysis indicates, out of 26 El Niño years, Indian summer monsoon rainfall was suppressed (< -10 % from long term average) during 11 years, enhanced during 4 years (> +10%) and remains normal rainfall condition (-10 to +10 %) during 11 years. During 1901 to 2010, North East monsoon during October to December over India was enhanced during 15 El Niño years, which is 89% of El Niño years during this period (Figure 4.3). The North East monsoon has a higher correlation with El Niño than the South West monsoon in India. This type of consistent signals would help preparing the potential impacts based on forecast, which would lend confidence against taking informed decision making process.

A case of representing potential impacts of El Niño on weather parameters in India

The likely conditions of the extreme precipitation and temperature over a country (e.g. India) could be represented as shown in Table 3.1 (Adopted from Hirons and Klingaman (2016))

<table>
<thead>
<tr>
<th></th>
<th>Very likely</th>
<th>Likely</th>
<th>Likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Extremely Cold</td>
<td>No consistent signal</td>
<td>Extremely hot</td>
<td></td>
</tr>
<tr>
<td>Rainfall</td>
<td>Extremely Wet</td>
<td></td>
<td>Extremely dry</td>
<td></td>
</tr>
</tbody>
</table>

The dark blue colors for temperature – corresponding to “Very Likely Extremely Cold” conditions – can be interpreted as extreme cold conditions in that season, in that country as being at least twice as likely to occur during El Niño.
5. Assessment of Likelihood of Extreme Events in Respect of Seasons and Regions within the Country (Step-4)

The aim of step-5 is to characterize the variation of El Niño induced weather impacts during various months/seasons at sub-national level.

As there are space-time variation exist in the distribution of weather parameters even during the normal season because of climatological zones, contextualizing region-wise and season-wise becomes important for assessing the impacts of El Niño. For instance, the spatial variation of rainfall characteristics during Jun-Sep and Oct-Dec months of 2015-2016 (strongest El Niño year in the recent history) is shown in Figure 4.1 and 4.2.

![Figure 4.1 Jun-Sep 2015 rainfall anomaly from climatological normal (1981-2010)](image1)

![Figure 4.2 Oct-Dec 2015 rainfall anomaly from climatological normal (1981-2010)](image2)
For each country or region, estimating the likelihood of temperature, rainfall extremes and cyclone frequencies occurring over different seasons (e.g. India summer monsoon season - June to September, winter season - October to March, pre-monsoon season - April to June, and subsequent summer monsoon season - June to September) would help contextualizing the impacts specific to different regions and seasons. For Pacific Islands, the likelihood of cyclone frequencies are critical, as it causes huge damage to agriculture and infrastructure leading to socioeconomic issues.

A case of rainfall variability in India during 2015-2016 El Niño episode over the space and time are discussed below. During 2015 summer monsoon season (June-Sep), India as a whole received -14% lesser than the normal. However, spatially the deviation varies within the country (Figure-4.3). For example, the negative departures are prominent over the central and northern part of India. There are huge variations observed during different months of the summer monsoon season. Though India received above normal rainfall during June 2015, the rainfall was heavily suppressed during the following months (Jul-Sep) as the monsoon progressed.

Contrastingly, the Northeast Indian monsoon during Oct-Dec 2015 was heavily enhanced over Southern peninsular India. The coastal districts of Tamil Nadu was heavily flooded and the city Chennai which is home to 10 million people got seriously affected. The rainfall characteristics during Oct-Nov 2015 and the flooding situation in Tamil Nadu is presented in box-4.1

<table>
<thead>
<tr>
<th>Box-4.1 Oct-Nov 2015 : Heavy rainfall episodes and floods in Tamil Nadu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamil Nadu coastal districts received around 1110 mm during 01 October 2015 to 25 November 2015, which is almost twice the normal rainfall. (Source: Indian Meteorological Department). The sudden downpour of rainfall episodes caused floods, flash floods and water logging in many parts of Tamil Nadu. The impacts are felt severe over the districts Chennai and Cuddalore, among the other districts. As of 10 Dec 2015, more than 300 people reportedly dead and more than 1.7 million people were evacuated. The Chennai floods caused heavy damages on housing and road infrastructure and the loss was estimated to be $2.2 billion.</td>
</tr>
</tbody>
</table>

Source: ACAPS, 2015
Even these space-time variation of dry and wet conditions during the El Niño years could be estimated using the probabilistic approach method from IRI. During the past El Niño years, the probability of wet, normal, and dry conditions during Jun-Aug months over Asia Pacific is shown in Figure 4.4 to 4.6. It is only some regions are having consistent signal for dry conditions during El Niño (part of Indonesia and India). Such analysis would help interpreting the probabilistic impacts at finer temporal and spatial scales.
Figure 4.4 Probability of dry conditions during Jun-Aug months of El Niño years
   Source: IRI

Figure 4.5 Probability of normal conditions during Jun-Aug months of El Niño years.
   Source: IRI

Figure 4.6 Probability of wet conditions during Jun-Aug months of El Niño years
   Source: IRI
Characterizing the deviations along with the probability in every specific region/location would help understanding the impacts specific to that region and its consistency. The assessment has to be carried out for different seasons (Jun-Jul-Aug, Sep-Oct-Nov, Dec-Jan-Feb, Mar-Apr-May, year+1 of Jun-Jul-Aug, year+1 of Sep-Oct-Nov) that captures the impacts of various stages of El Niño in that particular location for different periods, as there are huge temporal variation in the behavior of extreme events due to El Niño.

**Box 4.2 Impacts during different El Niño phases in Indonesia**

Hirons and Klingaman 2016 documented a case of 2015-16 El Niño impacts derived from the past analogues to show how the changes of extremes in temperature, precipitation varies during the pre-peak (Jun-Feb) and post peak (Mar-Nov) phases of an East Pacific (EP) El Niño event. The analysis is based on choosing 3 analogue El Niño events (1982-83, 1987-88, and 1997-98) over the last 35 years which are similar to 2015-16. Extremes are defined as being in the top (or bottom) 25% of the observed record at that location. The extremes were estimated for different seasons to understand the impacts of various stages of El Niño. For example, the change in the probability of extremes precipitation over Indonesia during the developing (pre-peak) phase of an East Pacific (EP) El Niño event from June-February indicates that drier conditions are more prevalent during Sep-Oct-Nov (2.5 times lesser than the lower quartile in the precipitation). The rainfall extremes indicate wetter condition over Indonesia during the decaying phase of El Niño. This indicate the assessment of extremes over different time steps give a different dimension of the impacts, which are critical for estimating the bio-physical and socio-economic impacts.

**A case of representing potential impacts of El Niño on weather parameters capturing subnational variability in India**

For some large countries, the impact of El Niño is not uniform across the entire country. In these cases, the tables have been annotated to show which area of the country is experiencing the extreme. For example the below table captures the variability in the regions, extreme dry conditions are very likely in the northern regions of India during June-August 2015 and in the southern regions during September-November.

An example for likely El Niño 2015-16 impacts in India is shown in Table 4.1

**Table 4.1 Likely El Niño 2015-16 impacts on seasonal temperature and rainfall in India**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>Temperature</td>
<td>N S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>Rainfall</td>
<td>N S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Regional impacts within each area can be denoted by letters (e.g. S = South, N = North, NE=Northeast, SW = Southwest).

The dotted line for the periods in the table indicate that they are free from the El Niño phases. Source: Hirons and Klingaman (2016).
Cyclone frequencies in Pacific Islands

The occurrence of tropical cyclones across the Pacific region during previous El Niño years show an increase in the frequency of cyclones affecting the central and southern islands, except Papua New Guinea, which has experienced fewer tropical cyclones (Figure 4.7). The Marshall Islands have been exposed to cyclones of a greater intensity, while Palau, Timor-Leste, Kiribati, and Vanuatu have experienced no changes in their exposure to tropical cyclones during El Niño years. These observations are mainly due to the shift in the position of cyclone formation towards the northeast during an El Niño event (Chand and Walsh, 2013). The observed patterns in the past could be used to interpret the potential impacts for the forecasted El Niño episode.

Figure 4.7 Cyclone frequencies during El Niño years in the Pacific Islands. Source: ESCAP and RIMES 2014b
6. Assessment of Biophysical Impacts (Step-5)

The aim of step-5 is to assess the biophysical impacts caused by the variations in the weather patterns induced by El Niño. The observed risk patterns/impacts in the past would give an indication about likely impacts for the future.

The positive and negative impacts of El Niño are widely recognized in Asia-Pacific on the following sectors: agriculture, water resource, ecosystem, infrastructure, and public health (Table 6.1). Depending on the shifting weather patterns and climate risk profile of a region, the biophysical impacts varies from region to region. The assessment of biophysical impacts are carried out to understand the sensitivity of different sectors to weather and climate variability during different El Niño years. The past knowledge will help estimating the potential impacts (probabilistically and not with absolute certainty) for El Niño forecasts to make informed decisions to manage the negative impacts. The approaches such as review of previous studies and research, case studies (individual cases, multiple cases), analog studies, predictive extrapolations are of great help in assessing the biophysical impacts (Riebsame, 1988). In this module, the participants will be introduced with various case studies to understand biophysical impacts of El Niño induced climate/weather variability. The case studies on assessment of biophysical impacts that document the varying impacts of El Niño on different sectors in the Asia-Pacific are discussed in the sections 6.1 to 6.5. The Desinventar Disaster Damage Loss database has a rich information on biophysical impacts for many countries in Asia-Pacific, that could be used in the assessment (http://www.desinventar.net/index_www.html)

**Table 6.1 Bio-physical impacts of El Niño**

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Negative impacts</th>
<th>Positive impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agriculture</strong></td>
<td>• Fall in crop production</td>
<td>• Optimal crop production unless it is not flooded</td>
</tr>
<tr>
<td></td>
<td>• Forest fire burning horticulture and agriculture lands in the forest fire prone zones</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Loss in subsistence agriculture</td>
<td></td>
</tr>
<tr>
<td><strong>Water resources</strong></td>
<td>• Drying up of rivers &amp; water bodies</td>
<td>• Enhanced river flow</td>
</tr>
<tr>
<td></td>
<td>• Falling of ground water level</td>
<td>• Surplus water in water harvesting structures and reservoirs</td>
</tr>
<tr>
<td></td>
<td>• Water scarcity for irrigation and drinking water supply</td>
<td>• Optimal ground water level</td>
</tr>
<tr>
<td><strong>Ecosystem</strong></td>
<td>• Forest fires</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>• Coral bleaching</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Land degradation</td>
<td></td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td>• Infrastructure damages due to floods and cyclones</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>• Damages to human settlements and critical infrastructures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Damage to irrigation and hydraulic structures</td>
<td></td>
</tr>
</tbody>
</table>
6.1 Agriculture Systems

The El Niño impacts differ from region to region based on the sensitivity of agro-ecological zones that could be estimated based on past impacts. The historical assessment of crop production performance during different El Niño years could give an idea to evolve scenarios of future impacts of El Niño of various magnitude and duration and projected future impacts. It is not always, the agriculture sector will face negative consequences during El Niño years. It varies based on various El Niño characteristics as explained in Chapter-3. The drought like conditions induced by El Niño might have a different impacts on rainfed and irrigated crop lands. The crops watered by irrigation are relatively less sensitive to short term precipitation fluctuations. Hence, an assessment has to holistically consider the region’s agricultural history, current farming and irrigation practice, and recent climate and crop productivity (Riebsame, 1988). The crop data on area planted, production quantity, and yield (season wise, crop wise) is critical to assess the performance during the past El Niño years. Additional information such as irrigation practices, mechanization and other coping mechanisms would also be considered based on the data availability. The crop production might give an approximate indication of its response to the El Niño induced climate variability. As there are other drivers influencing the crop production losses, a careful assessment is required. The documented case studies of agriculture impacts during the El Niño years in India (Box 6.1), Indonesia (Box 6.2), Philippines (Table 6.2), Sri Lanka (Box 6.3) and Fiji (Box 6.4) are discussed below. The case studies has to be considered as indicator for interpreting the future impacts in the respective region.

Box 6.1 Paddy production in India during El Niño years

Rice production in India fell by as much as 23 percent, or 32 million tons, during the El Niño in 2002. Substantial decrease in production quantity was also identified during the 2004 and 2009 El Niño years. Production fell by 8.4 percent or 12 million tons during the moderate El Niño of 2009, while the weak El Niño of 2004 depressed rice production by over USD 8 million tons (refer Figure 6.1).

![Figure 6.1: Paddy production in India from 2001 to 2012. Source: ESCAP and RIMES, 2014a](image-url)
Box 6.2 El Niño impacts on agriculture in Indonesia

The 1997-98 drought is reported to be the worst in half a century. The worst affected areas are southern Sumatra and Kalimantan, on the Island of Borneo, Java and eastern parts of the country. Overall, official estimates indicate that the drought affected some 300,000 hectares of rice. The dry conditions have also exacerbated fires which have affected agriculture and forest plantations and reduced water supplies.

The severe El Niño of 1997-98 resulted in substantial reduction in agricultural production. Indonesia has to import 5 million tons of rice and the country experienced severe inflation of food commodity prices to the extent of 138 percent. The impacts of subsequent El Niño events were less, but still a matter of concern.

The impact of El Niño on national annual food crop production is not consistent. El Niño starts in April/May and normally ends in June of the subsequent year. Typically, El Niño affects dry season, planting schedule of wet seasons and the dry season of subsequent year. Moreover, onset and termination of El Niño varies. The impact of El Niño should be measured over a period of two years. Keeping in view the impact duration of El Niño, the assessment of drought and crop production should vary from event to event.

The national level annual data conceal regional and seasonal differences. Hence, a study should take a district as a unit and crop calendar of that district as a basis for establishing relationships between El Niño and crop production. The farmers’ adaptation of switching crops needs to be accounted for. Over and above, the non-climate related shocks like the economic crisis of 1997 and its impact on farm economy needs to be accounted for. The guidelines have been designed to capture these peculiarities in Indonesia. A season-wise, province-wise information was to be collected for rice crop initially, and expanded to cover collection of month-wise and district-wise data.

Table 6.2: Documented Occurrences of agricultural impacts in the Philippines, 1982-1998

<table>
<thead>
<tr>
<th>El Niño year</th>
<th>Areas Affected</th>
<th>Damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982-1983</td>
<td>Western and Central Luzon, Southern Tagalog Provinces, Northern Visayas, Bohol and Western Mindanao</td>
<td>6.4x10⁵ MT of rice and corn; insurance claims amounted to Peso 38 Million;</td>
</tr>
<tr>
<td>1992-1993</td>
<td>Moderate to severe drought affected most of Luzon, Negros Occidental and Iloilo</td>
<td></td>
</tr>
<tr>
<td>1986-1987</td>
<td>Severe drought affected Bicol Region, Southern Negros, Cebu and Western Mindanao</td>
<td>Estimated agricultural damages of Peso 47 Million</td>
</tr>
<tr>
<td>1989-1990</td>
<td>Drought affected Cagayan Valley, Panay Island, Guimaras, Palawan and Southern Mindanao; affected rice and corn area totaled 283,562 hectares; major multipurpose water reservoirs reduced inflow</td>
<td>Estimated 5 x 10⁵ MT of rice and corn production losses;</td>
</tr>
<tr>
<td>1991-1992</td>
<td>Severe drought affected Manila, Central and Western Visayas and Cagayan Valley; affected agricultural area of</td>
<td>Peso 4.09 Billion agricultural losses; 20% shortfall in Metro Manila water supply</td>
</tr>
</tbody>
</table>
461,800 hectares

| 1997-1998 | About 70% of the Philippines experienced severe drought; about 292,000 ha of rice and corn area completely damaged | 622,106 MT of rice production loss and 565,240 MT of corn amounting to Peso 3 Billion; |

*Source: Philippine Atmospheric, Geophysical and Astronomical Services Administration*

At the same time, countries like Sri Lanka has favorable agriculture crop production during El Niño years (as shown in Box 6.3).

**Box 6.3 Paddy production in Sri Lanka during El Niño years**

There are two major cropping season in Sri Lanka, Yala (Apr to Sep) and Maha (Oct to Mar). Sri Lanka receives favorable rainy condition during Oct – Nov and hence has increased agriculture production during Maha season during the El Niño years. (Zubair, 2002) (see below figure 6.2).

![Paddy production in Sri Lanka](image)

*Figure 6.2: Season wise Paddy production in Sri Lanka from 1985 to 2012*

During the past El Niño years, Fiji’s sugarcane production was affected by the drier conditions influenced by El Niño, and the details of the impacts are presented in Box 6.4.

**Box 6.4 Climate sensitivity of sugarcane production in Fiji**

Fiji’s major crop is sugarcane which is sensitive to climate variability. Though El Niño is not the only factor affecting sugarcane production, El Niño associated losses seem to be evident from the fall in production in the subsequent year, as depicted in Figure 6.3.

![Sugarcane production in Fiji](image)

*Figure 6.3. El Niño impact on sugarcane production in Fiji*

*Note: The impact of El Niño on rice production is experienced in the year following the event*


The severe 1997-1998 event caused sugarcane production losses of more than 33 percent. The
2006-2007 episode registered a reduction of 21 percent, and the 2009-2010 event witnessed a production fall of over 16 percent. 

Source: ESCAP and RIMES, 2014a

Subsistence agriculture in Papua New Guinea, Solomon Islands, Fiji, Vanuatu, and Cook Islands is a significant component of GDP. In the past, the agriculture sector was affected during the El Niño years due to either cyclones or drought like conditions (as shown in the below table 6.3).

Table 6.3 Historical impacts of El Niño on agriculture in the Pacific Islands

<table>
<thead>
<tr>
<th>Country</th>
<th>Observed impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federated States of Micronesia</td>
<td>Prolonged drought due to 1997/98 El Niño caused stress on staple crops, especially taro, and depleted food supplies (UN OCHA, 1998)</td>
</tr>
<tr>
<td>Fiji</td>
<td>1997/98 drought caused 26% decline in sugarcane production, and led to decline in GDP of at least 1.3% (World Bank, n.d.); losses from livestock death amounted to around USD 7 million (McKenzie et al, 2005). During 2009, the western island received over 45 cm of rain in 24 hours that resulted to severe flooding of up to 3 to 5 meters, and severely damaged agriculture and infrastructure worth FS 100 million (SPC, 2010)</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>The 1997/98 drought severely affected subsistence farming, and significantly affected production of coffee and cocoa. About 1 million people suffered from food insecurity due to failure of food crops. The Australian government provided AUD 30 million in food aid to areas affected by drought (SPC, n.d.).</td>
</tr>
<tr>
<td>Tonga</td>
<td>Severe droughts in 1983, 1998, and 2006 caused stunted growth in sweet potatoes &amp; coconuts; livestock sector, particularly swine, were badly affected (The Kingdom of Tonga, 2012)</td>
</tr>
</tbody>
</table>

Source: ESCAP and RIMES, 2014b

6.2 Water Resources Sector

The changes in climate and weather characteristics (especially rainfall patterns) has a pronounced impact on runoff and the subsequent effects of changes in runoff on managed water supply systems (Riebsame, 1988). As the agricultural and domestic consumption heavily depend on the water resources, fluctuations in the water availability leads to serious consequences. Case studies are presented to capture the following aspects of impacts on water resource sector: 1) evaluate the influence of rainfall variability to the flow regime of main rivers/water level in reservoirs in different geographical regions, with reference to normal and El Niño years (Box 6.5 & 6.6), 2) estimate the availability and accessibility of ground water during the El Niño years (Box 6.7), and 3) infer any water quality issues in the past during El Niño years (refer Kiribati case in Table 6.4). In addition, the effective use of earth observation data in assessing the impacts is presented for a case of monitoring water level in Thailand (Box-6.8).

Box-6.5 Impact of El Niño in the water resource sector in Sri Lanka

During El Niño years, Sri Lanka receives excess rainfall during October-December, but this is not immediately reflected in the streamflow during October-December as some of the rainfall excess is used to replenish the anomalous dry soil moisture happened due to the dry period April-September. (Chandimala and Zubair, 2007). The stream flow in Mahaweli river basin is lower in the months of Jan to Sep during El Niño years. At the same time October to December stream flow has not been affected and it is almost the same as normal years due to
enhanced rainfall during these months due to El Niño. (Zubair, 2003)

**Box-6.6 Impact of 2015-16 El Niño in the water resource sector in Thailand**

Experiencing a second consecutive year of drought. Less-than-adequate rainfall in 2015 resulted in insufficient recharge of key reservoirs, which underpin much of the economy and the country’s drinking water supply. Reservoir supplies in late September are critically low, 40 to 50 percent below last year’s drought-affected level. As a result, the Thai government ordered a complete ban on irrigation water usage during the upcoming winter dry season rice crop. Thai farmers typically sow approximately 2.0 million hectares during the dry season, of which approximately 80 percent is fully irrigated. Given the existing water shortage and the official ban on agricultural irrigation usage, it is likely that 2015/16 dry-season acreage will substantially decline from both last year and the average.

Source: USDA, 2015

**Box 6.7 – Case of ground water resource issue in Vietnam during 2015-2016 El Niño year**

An estimated 2 million (400,000 households) people in the three regions do not have regular and sufficient access to water for human consumption and domestic use. Water shortage and use of unsafe water pose risk factors for outbreaks of water-related disease. In the Mekong Delta, the drought and related decrease in groundwater levels have resulted in the most extensive saltwater intrusion in 90 years. While salt water intrusion (which contaminates aquifers that support domestic water demand) is an annual phenomenon, it set in nearly two months earlier than normal in 2016 and has penetrated an average 20-30 km further inland than normal.

Since late 2015, the Government has provided 5,221 tons of relief food for distribution to the three drought-affected regions and has allocated 1008 billion VND (45 million USD) for drought relief efforts nationally. This has supported trucking of 2 million m3 of water and distribution of 630,000 doses of Chloramine B and 400,000 Aquatabs for water-insecure households. On 15 March 2016, the Government of Vietnam requested the support of international partners for their relief efforts, with priority given to ensuring water supply, storage and treatment in drought-affected areas, as well as food security and nutritional support and enhanced monitoring of potential disease outbreaks.

Source: UNOCHA, 2016

Small islands in the Pacific depend on freshwater lenses – thin layers of fresh groundwater, overlying seawater. Decreased rainfall threatens these lenses, especially in islands with relatively low mean rainfall such as Tonga, Cook Islands and Niue. A 25% decrease in the replenishment of groundwater reduces the thickness of the freshwater lens by about 50 percent (White and Falkland, 2010). The historical impacts of El Niño on the water resource sector in Pacific Islands are presented in the Table 6.4

**Table 6.4 Historical impacts of El Niño on water resource sector in the Pacific Islands**

<table>
<thead>
<tr>
<th>Country</th>
<th>Observed impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federated States of Micronesia</td>
<td>Prolonged drought due to 1997/98 El Niño caused many areas to be without water, or on water rationing (UN OCHA, 1998)</td>
</tr>
<tr>
<td>Kiribati</td>
<td>1997/98: shallow groundwater reserves became brackish (World Bank,</td>
</tr>
</tbody>
</table>


Palau | Water shortage due to prolonged drought in 1997/98 led to water rationing (Australian Bureau of Meteorology and CSIRO, 2011)
--- | ---
Timor-Leste | Reduced ground water availability is most significant El Niño impact (Australian Bureau of Meteorology and CSIRO, 2011)
Tonga | Prolonged droughts, such as in 1997/98, significantly impact shallow groundwater systems; seawater intrusion, due to storm surge associated with Hurricane Isaac in 1982, adversely affected freshwater lenses (The Kingdom of Tonga, 2012)
Vanuatu | Decreased rainfall and increase in evaporation associated with increased temperatures reduce the rate of groundwater recharge, affecting freshwater availability (FAO, 2008)

Source: ESCAP and RIMES, 2014b

**Box 6.8 Diminishing water levels in Pasak Chonlasit Dam, Thailand during 2015**

In Thailand, insufficient rainfall depleted water levels in reservoirs across the country, with 17 reservoirs having between 1 and 20 per cent useable storage in July 2015. Due to drought, farmers in Thailand postponed or avoided planting of crops. The extend of water availability (area) could be assessed through satellite images, for instance the satellite image showing water levels during Jan-Jul by every month is shown in Figure 6.5

![Figure 6.5. Diminishing water levels in Pasak Chonlasit Dam, Lopburi province, Thailand in 2015. Source: GISTDA 2015 cited at ESCAP 2016](image)

**6.3 Ecosystem Services**

The impacts of ecosystem can be assessed for land and ocean separately: 1) land ecosystem – forest fires and dry conditions affecting forest vegetation and habitats in the region, and 2) marine ecosystem - coral bleaching caused by abnormal sea surface temperature.

A case of 2015-16 forest fire impacts in Indonesia is presented in Box 6.9.

**Box 6.9 Impacts of 2015-16 forest fires on ecosystem in Indonesia**

The forest fires causes damage to the forest where the fires are occurring. Indonesia’s tropical forests represent some of the most diverse habitats on the planet. The fire outbreak during 2015-16 adds to decades of existing deforestation by palm oil, timber and other agribusiness.
operators. The fires threaten many ecologically important areas, including habitats for rare species like tigers and orangutans. The extent of forest fire smoke can be assessed through satellite images (Figure 6.6)

![Image](https://example.com/image.png)

*Figure 6.6 Heavy smoke pours from peat fires in Indonesia, blanketing six countries. Picture: NASA*


The coral reefs directly and indirectly supports approximately 500 million people worldwide for food and to protect coastlines from storms and erosion. The coral reefs supports the local economy by creating favorable ocean ecosystem for important fish species and tourism and they contribute approximately $29.8 billion to world economies each year (NOAA, 2016). Coral reef ecosystems sustain fishermen’s livelihood, support tourism, and mitigate storm surge impacts, hence are valuable assets for small island developing states. Increased sea surface temperature (SST) and tropical cyclone frequency during El Niño years threaten coral colonies. Abnormal SSTs in 1997/98 caused the observed bleaching of corals in the Pacific (see below Table 6.5). As the relationship between SST and coral bleaching are well documented, the SST can be used as an indicator for assessing the coral bleaching.

<table>
<thead>
<tr>
<th>Country</th>
<th>Observed impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiji</td>
<td>Coral bleaching cases reported due to warm SSTs in 1997/98 (World Bank, n.d.); increase in sea level, SST changes, and alteration of the mixing layer thickness affect plankton productivity (Government of the Republic of Fiji, 2013)</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>Coral bleaching cases reported due to warm SSTs in 1997/98 (World Bank, n.d.)</td>
</tr>
<tr>
<td>Tonga</td>
<td>Coral bleaching cases reported due to warm SSTs in 1997/98 (World Bank, n.d.)</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>Cyclone Ivy in 2003 caused considerable damage to coral reefs at Efate (FAO, 2008)</td>
</tr>
</tbody>
</table>

Source: ESCAP and RIMES, 2014b
The coral bleaching is a serious threat as the recovery takes years, for instance, coral bleaching occurred during 1997-1998 El Niño episode in Southeast Asia, some of the more rapid growing, branching corals recovered in 12 years period. However, the slower growing corals that build the backbone of reefs did not recover. The coral bleaching during the 2015-2016 El Niño poses a great threat as it has occurred six years after the 2009-2010 El Niño episode, which gives very less time for the corals to recover (NOAA, 2016). Such extended or permanent impacts has to be considered while assessing the impacts on marine ecosystem.

### 6.4 Infrastructure

The damages to infrastructure during El Niño years are mainly due to heavy downpour of rainfall, tropical cyclones. Damage from strong winds, intense rainfall, and surge could cost several times a country’s GDP in the Pacific Island nations (see below Table 6.6). The damages are direct losses that are documented by countries that could be used while assessing the impacts.

<table>
<thead>
<tr>
<th>Country</th>
<th>Observed impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niue</td>
<td>Damage from high winds, storm surge, and intense rainfall from Cyclone Heta in 2004 was three times the country’s GDP (Australian Bureau of Meteorology and CSIRO, 2011)</td>
</tr>
<tr>
<td>Samoa</td>
<td>Damage caused by Tropical Cyclones Ofa (1990) and Val (1991) estimated at four times the country’s GDP; flooding due to tropical cyclones in 2008 and 2011 damaged transportation and water infrastructure severely (Australian Bureau of Meteorology and CSIRO, 2011)</td>
</tr>
</tbody>
</table>

*Source: ESCAP and RIMES, 2014b*

### 6.5 Public Health

The El Niño caused shifting weather patterns such as severe drought, flooding, heavy rains and temperature rises can lead to food insecurity and malnutrition, disease outbreaks, acute water shortages, and disruption of health services (WHO, 2016). The health consequences will be more if the countries are having less capacities to cope with such threats. For instance, the Papua New Guinea and other pacific Island nations are at higher health risk compared to other countries in Asia-Pacific.

The historical impacts of El Niño on public health is presented in Box-6.10

**Box-6.10: El Niño impact on public health in the Asia-Pacific.**

**Pacific Islands:** Increased incidence of dengue during El Niño years is attributed to warmer temperatures, which increase the replication rate of the virus, and to storage of water due to less rainfall, which increases the number of mosquito breeding sites (Gagnon, Bush & Smoyer-Tomic, 2001). Dengue, associated with the 1997/98 El Niño event, affected 24,000 people and claimed 13 lives in Fiji (Government of the Republic of Fiji, 2013), and cost FJ$ 12 million (equivalent to US$ 6 million) in medical care and other direct costs (Raju in Singh et al, 2005). Tonga also reported dengue outbreaks during drought years (The Kingdom of Tonga, 2012). In Papua New Guinea, the incidence of malaria increased, as drought forced.

**Philippines:** Even the extreme climate events are huge threat to the countries in Asia. For
instance, the typhoon Koppu that made landfall in Central Luzon during October 2015 raised the threat of disease outbreaks, as similar natural disasters raised threats such as leptospirosis and dengue. Also, malnutrition could become a serious problem for children under five, as well as for pregnant women and new mothers (WHO, 2016).

**Indonesia:** Due to the forest fire in Indonesia during 1997-98, the health of over 20 million people was believed to be adversely affected in Southeast Asia in late 1997, particularly through upper respiratory tract infections and asthma. The young, the old and the infirm suffered particularly. (Byron and Shepherd, 1998). Even the toxic yellow cloud due to 2015 forest fires in Indonesia is disrupting transport, schools and business and caused hundreds of thousands of people to fall ill.


The health related risks during the El Niño year documented by World Health Organization is presented in figure-6.7. Hence, a careful interpretation based on the past experiences has to be carried out while assessing health related risk during an El Niño episode in a region.

**Potential bio-physical impacts based on El Niño forecast**

Based on the methodology discussed above, a case of El Niño potential bio-physical impacts in Indonesia for the year 2015-2016 is presented in Box- 6.11

**Box- 6.11 Potential bio-physical impacts in Indonesia during 2015-16 El Niño**

Drought during developing phase, reduction in water availability, crop production, threat of forest fires, flooding and landslides following peak are some of the impacts observed in the past El Niño years over Indonesia. Hence these conditions could be prevalent during the 2015-2016 El Niño event. The bio-physical impacts and the level of confidence are shown in...
the below table.

<table>
<thead>
<tr>
<th>El Niño phase</th>
<th>Drought</th>
<th>Flooding</th>
<th>Crop productivity</th>
<th>Water availability</th>
<th>Ecosystem</th>
<th>Infrastructure</th>
<th>Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Decaying</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

High (red) – Impacts are observed during >80% of El Niño analogue years, Medium (green) – Impacts are observed during 60-80% of El Niño analogue years, Potential (grey) – Impacts are observed during 40-60% of El Niño analogue years

Source: Hirons and Klingaman (2016)
The aim of step-6 is to assess the socioeconomic impacts that are linked to the biophysical impacts. The observed socioeconomic impacts in the past would give an indication about likely impacts for the future.

The variations in climate and weather characteristics causing biophysical impacts lead to have a differential negative impacts on the socio-economic conditions depending on the coping capacity. The socio-economic impacts can be classified under the following categories: food security and nutrition, inflation, unemployment, income, migration, conflict, poverty, and economy. The categories listed above are interlinked to each other. For example, if drought occurs, fall in crop production leads to food scarcity and inflation. The agriculture households and laborers lose their income and thereby poor purchasing power. The poverty among the people increases. For survival, people migrate to urban areas for employment. The social unrest are likely to occur during these distress conditions. All these impacts are likely to affect the household economy and extends up to macro economy. The household coping strategies and institutional interventions are two critical elements that has to be considered while assessing the impacts of drought at various stages of translation of meteorological drought to agricultural drought and then to socioeconomic drought.

Three aspects are discussed here: 1) Framework to assess the socio-economic impacts of droughts (induced by El Niño) on households, 2) food security and nutrition, and 3) Macro economy.

### 7.1 Framework for assessing socioeconomic impacts of drought

The socioeconomic impacts of drought depends on the response of the institution and households. A framework for assessing the socioeconomic impacts is shown in Figure 7.1 and the indicators that can be used to assess the impacts is presented in Box 7.1. The El Niño causing meteorological drought conditions leads to agricultural drought if no early drought onset measures on agricultural and hydrological operations are taken. For example, planting crops with less water requirement, delay or avoid water sensitive crops, irrigate with ground water could avoid transferring of meteorological drought to agricultural drought. Once agricultural drought happens, there are indicators representing reversible impacts and irreversible impacts can be observed in the society. The reversible strategies (risk minimization and absorption strategies) are adopted by households in order to avoid losing their productive assets. If the reversible strategies does not work, then indicators of irreversible strategies occurs for the survival by losing the productive assets of people. The crisis/emergency response by government institutions are required to avoid famine and ecosystem failure conditions. The indicators and response options has to be carefully assessed in order to estimate the socioeconomic impacts of drought.
Figure 7.1 Framework for socioeconomic impact assessment of drought

Box 7.1 Indicators for assessing socioeconomic impacts

Indicators for meteorological drought
- Poor rainfall distribution
- Extended dry spells

Indicators for agricultural drought
- Poor water availability for crops
- Drying of crops
- Poor crop production and yield

Indicators for reversible impacts on socioeconomic condition
- Change dietary habits
- Relied on less preferred, less expensive food Borrowed food
- Relied on help from friends or relatives
- Reduced the number of meals eaten per day
- Reduced portion size of meals
- Restricted consumption by adults in order for small children to eat
- Sold more animals (non-productive) than usual
- Withdrew children from school
- Sold household assets/goods (radio, furniture, refrigerator, television, jewelry etc.)
- Spend savings
- Purchased food on credit
- Reduced non-food expenses on health (including drugs) and education
- Migrate to urban areas for short term employment

Indicators for irreversible impacts on socioeconomic condition
- Sold productive assets or means of transport (sewing machine, wheelbarrow, bicycle, car, etc.)
- Sold last female animals
- Sold house or land
The failure of household reversible strategies leads to irreversible strategies for survival. If no institutional intervention happens, then it lead to serious famine situations, which normally happens in countries with very poor capacity.

Source: WFP, 2016

Based on the framework discussed above, two case studies that highlight socioeconomic impacts of drought are discussed below, Eastern Indonesia (Box 7.2) and India (Box 7.3)

**Box-7.2 2015-16 drought impacts in Eastern Indonesia**

In Eastern Indonesia, 59% household’s income were affected by the ongoing drought 2015-16, especially the households engaged in food crop production and those reliant on agricultural wage labor. As a primary response to reductions in income, the households reduced their food expenditure. These poor households are highly vulnerable for inflation in food prices. The food security issue arises because of their less purchasing power. To cope with the situation, households evolve strategies to overcome such situations. The indicators measuring the impacts of socioeconomic droughts in Eastern Indonesia is presented in the below table.

<table>
<thead>
<tr>
<th>Indicators for assessing reversible and irreversible impacts</th>
<th>Percentage of population affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sold more animals (non-productive) than usual</td>
<td>8</td>
</tr>
<tr>
<td>Sold household assets/goods</td>
<td>2</td>
</tr>
<tr>
<td>Reduced non-food expenses</td>
<td>12</td>
</tr>
<tr>
<td>Sold productive assets</td>
<td>0</td>
</tr>
<tr>
<td>Spent savings</td>
<td>8</td>
</tr>
<tr>
<td>Purchased food on credit or borrowed food</td>
<td>24</td>
</tr>
<tr>
<td>Sold house or land</td>
<td>0</td>
</tr>
<tr>
<td>Withdrew children from school</td>
<td>1</td>
</tr>
<tr>
<td>Sold last female animals</td>
<td>3</td>
</tr>
<tr>
<td>Relied on less preferred, less expensive food</td>
<td>23.2</td>
</tr>
<tr>
<td>Borrowed food or relied on help from friends or relatives</td>
<td>15.6</td>
</tr>
<tr>
<td>Reduced the number of meals eaten per day</td>
<td>16.4</td>
</tr>
<tr>
<td>Reduced portion size of meals</td>
<td>17.3</td>
</tr>
<tr>
<td>Restricted consumption by adults in order for small children to eat</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Higher percentage of households following the reversible strategies are indication of presence of socio-economic drought conditions, which requires institutional intervention before getting into irreversible strategies and then famine conditions.

Source: WFP, 2016

**Box-7.3 2015-16 drought impact on Bundel Khand Region, Madhya Pradesh, India**

In Madhya Pradesh, 35 out of 51 districts are declared as drought affected and sought central assistance of Rs.2,400 crore, indicating deepening rural distress. The following indicators are already noticed in Madhya Pradesh.

- Huge loss (2/3rd production was lost) in Kharif crops were recorded added to the less sown agricultural areas (only 40% agriculture land) due to drought.
The drinking water scarcity increased due to drying up of water in the hand pumps. Malnutrition was increased in children and women.

The debt ratio has been increased by 30% than last year through private money lender.

About 30% affected families had to withdraw their child from schools.

Agriculture laborer used to work for 50kgs of grain against harvesting a farm but due to scarce condition of employment people are ready to harvest a field only at 10kgs of grain.

As the migration is expected to double, employer will pay less wage rate as compared to earlier years. People have already started to migrate at nearby places like Raisen to work at Brick Klins. Another reason for migration is also to repay debts.

Low cost shops are already underperforming against its best capacities. Financial year end is said to be the reason for under distribution of food items.

Families having cattle have left them to survive on their own since these families cannot afford the fodder for livestock.

All these aggravated farmer suicides, as on average 2-3 farmers committing suicide daily.

The response options are not adequate to overcome the socioeconomic impacts. The effectiveness of response options were also documented.

- Compensation were distributed to only 60% effected families remaining 40% families still awaiting for government support
- The assured rural employment scheme implementation is very poor, Job card holders are not getting work, who already worked, not getting wages on time.
- Drinking water schemes is almost not functional and did not start any serious effort for drought mitigation
- In Tikamgarh, Panna & Chhatarpur districts are only 65% people are covered under food security act.
- Government public distribution system is on routine distribution, in this drought situation, no special distribution system adopted.

Source: SphereIndia, 2016

7.2 Food Security and nutrition

The food security is a serious issue in many parts of Asia-Pacific during El Niño years. For example, it is documented in Philippines (Box 7.4) that the effects of the El Niño felt by small-scale farmers result in poor nutrition and recurrent infections in children from conception to their second year of life that make them impaired physically and mentally and more prone to death and diseases (ACF, 2015). Similarly, Timor Leste also experienced food security issues during El Niño years. A case of food security and nutrition in Timor Leste is presented in the below Box-7.5.

**Box-7.4 Scenario of food security in Philippines**

55 percent of the population of 98 million live in rural areas. The effects of the El Niño are mostly felt by small-scale farmers and those who are fishery-dependent. Poverty is considered the most important factor in determining disaster vulnerability, and the proportion of Philippine families in extreme poverty was estimated at 7.6% during the first quarter of 2014. The estimated number of extremely poor families is around 1.61 million.

Three-quarters of the population in the 18 provinces of most-affected Mindanao fall under...
levels 2, 3 and 4 of the IPC44, with an estimated 1.96 million people suffering from severe chronic food insecurity (CFI), 3.67 million people from moderate CFI and 7 million people from mild CFI. Access to quality food and diversification of food consumed is poor, while the provinces classified under levels 3 and 4, indicate high prevalence of stunting, poor access to improved water source and low breastfeeding rates. The impact of the El Niño will build up a food security and nutrition situation that is already alarming in this part of the country.

Source: ACF, 2015

Box 7.5 Case of food security and Nutrition in Timor Leste during El Niño 2015-2016

While most communities across the country have been affected by the slow-onset of El Niño, the level of impact is variable between municipalities. In some areas, rainfall levels were up to 68 per cent less between October 2015 and January 2016, compared to the 2014/2015 wet season (which generally lasts from December to May) leading to delayed crop planting and significantly reduced yield, while water access and food security are key immediate concerns.

According to the Ministry of Agriculture’s rapid assessment, 45.9 per cent of households across the country are likely to experience food insecurity from April to June 2016, with 120,000 people severely affected across five municipalities (Lautem, Viqueque, Baucau, Covalima and Oecusse). Authorities have acquired 9,000 tons of rice for immediate distribution. Additional relief services to the severely affected municipalities are being planned by the Government, including provisions to stock six to seven warehouses with food supplies.

An Emergency Response Plan has been developed articulating assessed needs and planned response activities. WASH, Food, Nutrition, Health, Livelihoods and Education (with focus on water supplies and school feeding programs) were identified as priorities. Overall funding requirement for the response is estimated at US$25 million.


7.3 Macro Economy

The growing threat of El Niño on the society extends beyond the global climate system. As the world becomes increasingly integrated, the impacts of El Niño in one part of the world can be felt in other regions. This is especially true for climate-dependent agricultural commodities, which many countries depend on as an income source. There is value, therefore, in developing a systematic method in summarizing the impact of El Niño on the global macro-economy. Only through understanding how El Niño affects growth can policy makers begin to tackle it. A case of El Nino impacts on national output and price level is presented in Box 7.6

Box 7.6 El Niño’s impacts on national output and price level

Impacts on national output

A recent research project carried out by the International Monetary Fund (IMF) has concluded that El Niño scenarios likely have a negative impact on levels of national output.
Moreover, countries with a high proportion of primary sector (agriculture) is especially vulnerable to El Niño impacts. In addition, the impacts of El Niño is persistent, and can be seen even after 4 quarters of the initial shock (Figure 7.2).

In Asia-Pacific, the impacts of El Niño was felt in many agriculture-intensive nations. Weak monsoons and rising temperatures can adversely affect India’s agriculture sector. In 2015, severe drought in India has contributed to a revision of India’s growth figures from 8.1-8.5% to 7.0-7.5%. Similar scenarios were also observed in Indonesia and Japan, where increased frequency of typhoons has dampened consumer spending. In New Zealand, El Niño induced droughts has led to lower agriculture output. This has had a significant impact of GDP growth rate. However, it should be noted that sufficient planning can reduce the negative effects on output. In the case of Philippines, extensive early-warning systems including water supply management has negated significant negative effects on output.

**El Niño’s impacts on price level**

El Niño affects prices of commodities and agricultural products. In Australia, hot and dry summer in southeast parts of the country has led to increases in bush fires and reduced wheat production. This drove up global wheat prices. Indonesia’s drought has led to higher prices for coffee, cocoa, and palm oil. Moreover, the impacts of El Niño extends to non-agriculture commodities. For example, mining equipment in Indonesia relies heavily on hydropower. Insufficient rain leads to lower river currents and this hinders nickel production. Also, high temperatures and droughts increases the demand for coal and crude oil as lower electricity output is generated from thermal power plants and hydroelectric dams, leading to increases in coal and oil prices.

For many countries, increases in commodity and food prices will lead to upward pressure on inflation. This is especially true for agriculture-intensive countries such as India, Indonesia, and Thailand, where high weights are placed on food in the Consumer Price Index (CPI) basket. The IMF has found a significant positive relationship between food weight in CPI and inflation response following an El Niño shock, and this is after government interventions which attempted to offset the El Niño impacts.

The El Niño impacts on the economy varies from country to country depending on the shocks on various sectors such as agriculture, water resources and infrastructure etc., There are various ways to assess the macro economy impacts, however two aspects are discussed here: 1) How the impacts on agriculture sector affects the national
Cascading impacts of Agriculture sector

The drier conditions resulting in the loss of agriculture sector could have a cascade impact on secondary and tertiary sector for agriculture dominant countries in Asia such as India and Indonesia. At the same time, wetter conditions could result in profitable agriculture production, for instance, Tamil Nadu and Sri Lanka. The shocks experienced in the agricultural sector, and then cascades to secondary and tertiary sectors is discussed in Box 7.7.

Box 7.7 Methodology for assessing potential economic impacts

The immediate shock of rain failure is experienced in the agricultural sector, and then cascades to secondary and tertiary sectors through four major ways:

i. A backward linkage in the shortage of raw materials for agro-processing industries;
ii. A forward linkage in the reduced demand of industrial goods because of reduced agricultural income;
iii. A shift in the share of consumer demand away from industrial products because of high cost of food and agro processing necessities; and
iv. A potential shift in public sector investments for development in order to finance activities such as drought relief, etc.

A fall in aggregate demand in the agricultural sector in India is likely to cause serious constraint in production and demand of the industrial sector. Experience of past decades indicates that 1 percent fall in agricultural GDP causes a 0.52 percent fall in industrial output and a 0.24 percent fall in the service sector, with an overall deceleration of 0.52 percent in GDP (Sastry et al).

The following steps were followed to assess the potential impacts due to the anticipated El Niño in 2014:

i. An anticipated fall in agricultural GDP (in comparison to the previous year) is estimated based on past impacts of similar El Niño events;
ii. A factor of 0.52 (for India) and slightly adjusted factors for other countries (based on contribution of agriculture to overall economy) was used to multiply the agriculture growth rate impact to estimate the likely impact on overall GDP growth;
iii. The fall (or rise) in overall GDP was converted to absolute terms to arrive at the estimated impact in USD.

Based on the methodology discussed in Box 7.7, potential economic impacts were estimated for 2014/2015 El Niño based on the forecast products based on the past analogues (Box 7.8)

Box 7.8 Potential economic impacts estimated based on El Niño forecast 2014-2015

Scenario 1: If the onset is in August, South Asia, East Asia, and the Pacific could be impacted
by less than normal rainfall conditions. Although this likelihood is 60 per cent, as already the monsoon conditions have set in, the impact could be moderate in this scenario (Table 7.1). The cumulative impacts in the representative countries could have been in the order of USD 30 billion, as elaborated in Table 7.1. The impact of the event on agriculture and on the overall GDP varies across countries, ranging from USD 23 billion in the case of India, USD 7.7 billion for Indonesia, USD 983 million in Thailand and USD 29 million in Fiji.

Table 7.1 Potential impacts on macro-economy: Scenario-1 (onset in August)

<table>
<thead>
<tr>
<th>Sub region</th>
<th>Country</th>
<th>Agriculture GDP growth fall in 2014 with respect to 2013 (per cent, estimated)</th>
<th>Impact on GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Per cent</td>
</tr>
<tr>
<td>South Asia</td>
<td>India</td>
<td>-3</td>
<td>-1.56</td>
</tr>
<tr>
<td></td>
<td>Sri Lanka</td>
<td>2</td>
<td>0.49</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>Thailand</td>
<td>-1</td>
<td>-0.43</td>
</tr>
<tr>
<td></td>
<td>Indonesia</td>
<td>-3.5</td>
<td>-1.75</td>
</tr>
<tr>
<td>Pacific</td>
<td>Fiji</td>
<td>-5</td>
<td>-0.9</td>
</tr>
</tbody>
</table>

Scenario 2: As the South-West monsoon would have already ended, there could be less significant impacts of El Niño in South Asia and South-East Asia. The North-East monsoon could be favourable for Southern India and Sri Lanka, but unfavourable for the Philippines, Indonesia and South-West Pacific islands. Cumulative impacts in the representative countries could be in the order of 7 billion USD, as elaborated in Table 7.2.

Table 7.2 Potential impacts on macro-economy: Scenario-2 (onset in or after September)

<table>
<thead>
<tr>
<th>Sub region</th>
<th>Country</th>
<th>Agriculture GDP growth fall in 2014 with respect to 2013 (per cent, estimated)</th>
<th>Impact on GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Per cent</td>
</tr>
<tr>
<td>South Asia</td>
<td>India</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sri Lanka</td>
<td>2</td>
<td>0.49</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>Thailand</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Indonesia</td>
<td>-3.5</td>
<td>-1.75</td>
</tr>
<tr>
<td>Pacific</td>
<td>Fiji</td>
<td>-5</td>
<td>-0.9</td>
</tr>
</tbody>
</table>

Source: ESCAP and RIMES, 2014a

7.3.2 Annual Average Loss (AAL) and El Nino amplification factor

AAL refers to the long-term expected losses per year, averaged over many years. The AAL captures long-term expected losses, as a yearly average, over a given period of time. It is the weighted average of expected loss from every disaster event, given their probability of occurrence. AAL includes measurements of both direct damage and indirect losses, and takes into account exposure and vulnerability data, plus past disaster occurrences and their impacts.

Unlike historical estimates, AAL is inherently forward-looking. It considers the possibilities of all disaster occurrences through incorporating small frequency, high
damage disaster risks that have not been experienced yet. As a result, the analysis will not be biased towards disasters that occurred in the past, but contain a more comprehensive picture of what can be expected given current climate dynamics and socio-economic developments.

The general procedure of calculating AAL consists on an individual evaluation of losses for each hazard scenario, and a subsequent probabilistic integration of these results, using the frequency of occurrence of each scenario as a weighting factor.

The AAL utilizes data from Hazard (frequency and severity of events at a specific geographical location), exposure (infrastructure or population components that can be affected by a specific event), and vulnerability (determined by relating the level of damage with the intensity of the phenomenon) to determine a specific scenario’s forward-looking risk. The risk for a given area estimate is based on combining probabilistic hazard models and vulnerability functions for exposed assets.

The result of this combination is a Loss Exceedance Curve (Figure 7.3). The Loss Exceedance Curve depicts the relationship between estimated loss and risk of occurrence. It illustrates the relationship between frequency and severity. Different disaster scenarios will have different Loss Exceedance Curves. For example, infrequent but high impact events, like earthquakes, will have lower and flatter curves.

Reference: UNISDR, 2011

Figure 7.3 Example of a Loss Exceedance Curve for different disasters

The 2015 Global Assessment Report (GAR) has applied the AAL metric at the country level globally. Examples from Fiji and Papua New Guinea are provided below. In Fiji (Figure 7.4), the majority of potential disaster impacts comes for storms and cyclonic winds, while residential sectors are the most at risk. In Papua New Guinea (Figure 7.5), flood takes the majority of AAL composition and the services sector is the most vulnerable.
The economic losses during El Niño years can be calculated by multiplying the Annual Average Loss (AAL) and El Niño amplification factor. The annual average losses caused by climate related hazards during the normal years are assumed to be amplified during El Niño years. The details of AAL and El Niño amplification factor are discussed below. Further a case of estimating potential economic losses in the Pacific Island during El Niño year is presented in Box 7.9.
Climate events such as El Niño can amplify the potential impact of natural disaster events. The El Niño amplification factor is a rough-and-ready way of calculating the potential additional losses in the case of El Niño event in a country. It is found using the ratio of country-level climatological parameters in the no-El Niño case and El Niño case. For example, if 3 storms are expected in no-El Niño event and 5 storms are expected in El Niño event scenario, the amplification factor will be $5/3 = 1.67$. The table below shows the El Niño used in conjunction with AAL of selected Pacific Island Sates.

<table>
<thead>
<tr>
<th>Country</th>
<th>AAL (Million USD)</th>
<th>El Niño associated amplification factor</th>
<th>Potential losses (Million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall Islands</td>
<td>3.7</td>
<td>2.7</td>
<td>10.1</td>
</tr>
<tr>
<td>Papua Guinea</td>
<td>27.9</td>
<td>1</td>
<td>27.9</td>
</tr>
<tr>
<td>Tuvalu</td>
<td>0.1</td>
<td>1.43</td>
<td>0.14</td>
</tr>
<tr>
<td>Cook Islands</td>
<td>6</td>
<td>1.46</td>
<td>8.76</td>
</tr>
<tr>
<td>Fiji</td>
<td>94.1</td>
<td>1.04</td>
<td>97.86</td>
</tr>
<tr>
<td>Niue</td>
<td>1.1</td>
<td>1.33</td>
<td>1.46</td>
</tr>
<tr>
<td>Samoa</td>
<td>8.5</td>
<td>1.41</td>
<td>11.99</td>
</tr>
<tr>
<td>Tonga</td>
<td>11.7</td>
<td>1.14</td>
<td>13.34</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>44.3</td>
<td>1</td>
<td>44.3</td>
</tr>
</tbody>
</table>

Reference: ESCAP, 2014
8. Assessment of Likelihood of Extended Impacts vis-à-vis Livelihood Recovery (Step-7)

The aim of step-7 is to assess the likelihood of extended impacts due to socioeconomic impacts. The documented cases in the past would give an indication about likely impacts for the future.

Step-7 focuses on demonstrating the likelihood of extended impacts of El Niño and the recovery from the impacts. Especially, the impacts on the agriculture sector experienced by small scale farm holders.

The impacts of El Niño could even last after demise of El Niño and normalcy of weather patterns due to the livelihood recovery process and socioeconomic conditions. Even after the drought condition ends, depending on the socio-economic aspects and livelihood conditions, the recovery process takes time. As 87% of the world’s 500 million small farms (owns less than 2 ha land) are in Asia and the Pacific region (IFAD, 2016), they are more prone to extended impacts and delayed recovery due to socioeconomic status and access to grain inputs.

The small farm holders may not recover faster though the El Niño is over and rainfall gets resumed, and it can be measured with the following indicators

- Lack of grain inputs
- Poor access to credit and loans
- Inflation of grain prices affecting the purchasing capacity
- Poor water level in reservoirs for irrigation during the next planting season
- Land preparation of degraded land because of the current dry conditions.

A case of extended impacts on the subsistence farmers of Pacific island countries are discussed in the box 8.1.

Box 8.1 Case of subsistence farmers of Pacific Island countries

The subsistence farmers of Pacific Island countries suffering from El Niño associated droughts during the cropping season from November 2015 – May 2016 may not recover till next harvest season till May 2017 even though current El Niño event may end in April 2016. This is because these farmers are expected to resume farming operations during Nov 2016 and the harvest is expected in May 2017 assuming that this season is free from El Niño 2015-16 event.

The indicators listed above could be used to assess the extended impacts, so that the full spectrum of the impacts of El Niño are captured during the process of impact assessment.
The aim of step-8 is to communicate the risks of El Niño to various stakeholders for them to prepare strategies to minimize the negative impacts.

Effective risk communication is vital for disaster risk reduction. Hence, it is critical to understand effective risk communication processes that play a key role in making the stakeholders to understand the risk of El Niño to make appropriate informed decisions to minimize the negative impacts and consequences. For example, a consensus outlook was released well ahead of time on above normal rainfall conditions over Tamil Nadu (India), Sri Lanka and Maldives, jointly by WMO, IMD/Government of India, RIMES and CIDA. As forecasted, Tamil Nadu had an expensive flood disaster due to heavy downpour during the North East monsoon season. This case highlights the huge gap existing in terms of communicating the risk to the decision makers in the various sectors for taking informed decisions based on forecast products. Therefore these gaps has to be addressed through a well-established risk communication mechanism among the agencies.

The El Niño risk information is only useful if information is received, understood, and acted upon by those at risk. Weather information is only one “input” into to broader decision-making process on how to respond to a disaster. Despite advances in weather forecasting technology, it remains challenging to present forecasts and warnings in way that initiates behavioral responses. Therefore, there is a need for El Niño impact information to beyond physical metrics, but to focus on the need of the end user.

Impact-based El Niño forecasting focuses on the needs of the end user. It extracts relevant weather information and uses it as part of impact estimations. Information is presented as potential impacts, instead of physical weather attributes. This supports El Niño impact information users such as response personnel and decision makers. Impact-based forecasting focuses on user-needs. Figure 9.1 illustrates the process of weather information “translation” from weather analysis and forecast data to impact estimation and response and mitigation strategies.

Reference: Baode Chen and Xu Tang (2014)

*Figure 9.1 – Framework for translating weather information into response actions*
The above explained framework can be disseminated through the process called monsoon forum (Box-9.1), a best practice that connects science, institutions and society. During the monsoon forum, various stakeholders and meteorological department are brought together to discuss about the seasonal climate characteristics and its implication to various sectors. This facilitates the dialogue between cross-sectoral agencies and thereby better understanding of forecast products, and also to know what it means to them. For instance, monsoon forum processes are conducted in Myanmar, Sri Lanka, and Maldives. The risk communication of El Niño episodes has to be integrated into the seasonal monsoon forum process which would have a better impact on decision making process.

**Box 9.1 Monsoon forum – Connecting Science, Institution and Society**

Impacts of climate variability, extremes, and change on societies may be exacerbated by development decisions that are not guided by climate information. Application of climate information to anticipate events and guide decision-making is not optimum due to gaps that exist in the end-to-end information generation and application system. These gaps include limited user understanding of forecast products, mismatch between users’ needs and available climate products and services, and limited institutional mechanisms to facilitate efficient and effective translation and communication of information to and receive feedback from users.

The Seasonal Forum is a platform for regular dialogue between the National Meteorological and Hydrological Service (NMHS) and multi sectoral forecast users, aimed to address these gaps. The Seasonal Forum is a cyclical process of forecast provision by the NMHS; forecast users’ analysis of potential impacts on their sectors based on the forecast, identification of impact management options, providing feedback at the end of the season on actions taken during the course of the season, and identification of recommendations for improving forecast product generation and provision, as well as application; and NMHS improvement of products and provision of services to meet user demands.

The main objectives of this forum are to

- Ensure that forecast products, including their limitations and uncertainties, are communicated to and understood by users
- Encourage forecast applications for optimizing resource management and mitigating risks in climate sensitive sectors
- Receive user feedback for improving usability of forecast products
- Provide a platform for inter-agency coordination of policies, sectoral plans, and programs for managing potential impacts
- Provide a platform for long-term process of understanding climate opportunities/risks

Source: RIMES

In terms of infographics, the communication approach used by Hirons and Klingman (2016) could be used with a focus on communicating risks on different sectors and its level of confidence using color codes. The impacts can be summarized by sector with the uncertainty of the impact in these sectors are represented by the colored texts: red, green and beige correspond to high, medium and potential impacts respectively.

The risk patterns of the following *crop productivity, water availability, drought, flooding, migration/displacement of population, infrastructure, economy, health, and food security*, could be color coded using three different colors: High (red) – Impacts are observed during >80% of El Niño analogue years, Medium (green) – Impacts are observed during 60-80% of
El Niño analogue years, Potential (grey) – Impacts are observed during 40-60% of El Niño analogue years

The case of using these color coding in the risk communication of potential El Niño impacts during 2015-16 for Indonesia (Table-9.1) based on the past analogues are presented below for demonstration purposes.

Table 9.1 Potential impacts of El Niño in Indonesia

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<td></td>
<td>- Economy</td>
</tr>
</tbody>
</table>

Drought during developing phase, reduction in water availability, crop production, threat of forest fires with health-related risk. Flooding and landslides following peak with risk of increased dengue fever

Source: Hirons and Klingman (2016)
Exercise on potential impacts of El Niño


The current 2015-2016 El Niño is categorized as very strong magnitude and caused noticeable impacts on weather and climate system that affected various sectors in a different way. The impacts 2015-2016 El Niño is well documented by national governments, regional agencies, UN agencies and media. Having this experience recently, how will you assess the impacts of El Niño, if there is an El Niño forecast in future? The participants will assess the potential impact on weather/climate characteristics for their region of interest and further how it translates into biophysical and socioeconomic impacts based on the methodology discussed during the workshop sessions. The participants can choose their region and sectors which they are familiar with, so that their assessment can be shared with other participants at the end of the exercise.

- Follow the instruction and carry out the exercise through interactive discussion.
- Present your summary/finding to other participants in 10 mts.

ENSO forecast and characterization

Assuming you receive ENSO forecast from global centers that the El Niño is likely to have onset during the month of April 2019 (Step-1) and it resembles the characteristics of El Niño 2015-16 (Step-2) based on the following aspects

- Abnormal warming is likely to be observed over the entire Pacific Ocean basin
- Onset is likely to occur between April-June
- Antecedent El Niño like condition prevails before the likely El Niño onset

1. Assessment of El Niño and its impact on weather patterns (Step 3 to 4)

Assess the potential impacts of El Niño conditions described in the above section “ENSO forecast and characterization”. Infer the general characteristics of weather impacts (rainfall pattern, temperature, cyclone frequency) at national (Step-3) and subnational level by seasons (Step-4). Make use of the poster maps to infer the characteristics of subnational level impacts for your region of interest for different season. Meteorology department can take the lead, facilitate the dialogue with their colleagues, write down two points from step-1 to Step-4 and discuss.

2. Assessment of altered weather patterns (Step 5)

Assess the potential impacts of shifting weather patterns (deviations in cyclone frequency, rainfall and temperature departure) in various sectoral agencies. The assessment becomes possible only when there is a comprehensive disaster database and understanding of sectoral sensitivity to climate exists. For exercise, refer the risk patterns of past El Niño and observed impacts of El Niño during 2015-16 in the UNESCAP and RIMES outlook report. Sectoral agencies, NDMO, NGO, and...
Subnational government office takes the lead and facilitate the dialogue with their colleagues, and write down two points for Step-5 (mainly impacts during the El Niño year, especially 2015-16) and discuss.

3. Assessment of socioeconomic impacts (Step 6)

From your past experience, how the biophysical impacts are translated into socioeconomic impacts. Discuss how the household economy and national economy gets affected? Discuss how you measure the socioeconomic impacts in terms of indicators representing the household adjustment strategies, market price, labor market etc.? The impacts of macro economy can be calculated by multiplying the AAL by an amplifying factor which comes from the past experiences/empirical studies. Evaluate and discuss about the macroeconomic impacts during this forecasted 2019-2020 El Niño year?

Sectoral agencies, NDMO, NGO, and Subnational government office takes the lead and facilitates the dialogue with their colleagues, and write down two points for Step-6 (mainly the socioeconomic impacts observed during the El Niño year, especially 2015-16) and discuss what intervention from government would help overcoming such situations.

### AAL for selected countries in Asia Pacific

<table>
<thead>
<tr>
<th>Country</th>
<th>AAL (million US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>251.2</td>
</tr>
<tr>
<td>Fiji</td>
<td>131.82</td>
</tr>
<tr>
<td>India</td>
<td>9,824.87</td>
</tr>
<tr>
<td>Indonesia</td>
<td>3,574.98</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>0.25</td>
</tr>
<tr>
<td>Myanmar</td>
<td>2,077.86</td>
</tr>
<tr>
<td>Palau</td>
<td>13</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>169.84</td>
</tr>
<tr>
<td>Philippines</td>
<td>7,892.65</td>
</tr>
<tr>
<td>Samoa</td>
<td>14.7</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>166.54</td>
</tr>
<tr>
<td>Thailand</td>
<td>2,619.40</td>
</tr>
<tr>
<td>Timor Leste</td>
<td>15.8</td>
</tr>
<tr>
<td>Vietnam</td>
<td>2,376.07</td>
</tr>
</tbody>
</table>

Source: GAR 2015

4. Assessing extended impacts (Step-7)

Discuss your experience from countries, how the extended impacts are observed during the slow onset disasters like drought?

5. Communicating risk (Step-8)

Discuss your experience from countries, how the risks of El Niño are communicated at present? Based on your learning through this workshop, how would you do this in future?
References


Baode Chen and Xu Tang (2014) Translating weather forecasts into impact-relevant information, Talk given at the World Weather Open Science Conference, Montreal, Canada, August 2014


Chen M.A. (1991). Coping with seasonality and drought. SAGE publications, New Delhi, India


FAO (2008). Climate Change and Food Security in Pacific Island Countries, Food and Agriculture Organization, Rome, Italy.


