MAINSTREAMING WEATHER AND CLIMATE INFORMATION APPLICATION FOR AGRO-ECOLOGICAL SYSTEM RESILIENCE IN A CHANGING CLIMATE

TRAINING COURSE ON

AGRO-ECOSYSTEM RESILIENCE IN A CHANGING CLIMATE

|COURSE WORKBOOK|

Training Course on

Agro-Ecosystem Resilience in a Changing Climate

The development of this training course is part of the project called **"Mainstreaming Weather and Climate Information Application for Agro-ecosystem Resilience in a Changing Climate."** Launched in 2016, the project is been implemented by **Asian Disaster Preparedness Center (ADPC)** in collaboration with **the University of Peradeniya in Sri Lanka, Small Earth Nepal in Nepal, Sub-Institute of Hydrometeorology and Climate Change (SIHYMECC) in South Vietnam, United Nations University in Japan** and **the Indian Institute of Technology, Kharagpur in India.** The project has been funded by the **Asia Pacific Network (APN), Japan** under its Capacity Development Programme (CAPaBLE) that aims to enhance capacities of scientists, policy-makers and other relevant stakeholders in the Asia and Pacific region and to identify and assess global change issues at local, national and regional levels." The project reference no. is CBA2016-04MY-Dutta.

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Approach to the Course on
Mainstreaming Weather and Climate Information Application for Agro-Ecological System Resilience in a Changing Climate

The course introduces basic terminology used by practitioners of disaster risk management (DRM). In the study of resilience of agricultural systems, two terms introduced and described are *"Agro-ecosystems"* and *"Social-ecological systems"*. Majority agro-ecological systems are rural. The main thrust in building resilience of rural social ecological systems is ensuring sustainability of livelihoods, which underwrites food security of rural communities.

The traditional approach to the study of agro-ecosystem focuses on farming of crop species and livestock on land. However according to FAO (1988)[1] , *"aquaculture"* is defined as the equivalent of farming of both animals (including crustaceans, finfish and molluscs) and plants (including seaweeds and freshwater macrophytes) in fresh water as well as brackish and sea water in coastal areas. From a coastal livelihood approach, capturing fish from the river or sea considered as harvest of fisheries. All these contribute to the diversity of livelihoods.

Lescourret *et.al.* (2015)[2], state that forestry and inland aquatic systems, if considered as agricultural systems, cover about 40% of the continental surface of the Earth. Singh (2008) suggests that appropriately designed Community Based Forest Management policy can provide means to sustain and strengthen community livelihoods and at the same time avoid deforestation, restore forest cover and density, provide carbon mitigation and create rural assets[3].

FAO (2015)[4] has considered Fishery and Forestry as sub sectors of agriculture in assessing impact of disasters on the agriculture sector.

This Course adopts a broader paradigm where resilience of agro-ecological systems is entwined with concepts of sustainable livelihoods and food security. It embraces a view of agro-ecosystems inclusive of land farming systems& livestock, aqua culture, fishery and forestry practices which strengthen rural livelihoods, their sustainability and diversity, and contribute to food security.

It endeavors to provide the participant with know-how on analyzing factors that influence sustainability and resilience of agro-ecosystems and develop interventions to sustain productivity of these systems in the face of climate change by integrating weather and climate information.

[1] *http://www.fao.org/docrep/003/x6941e/x6941e04.htm*

[2] *Lescourret Françoise, Magda Danièle, Richard Guy, Adam-Blondon Anne-Françoise, Marion Bardy, Baudry Jacques,   Doussan Isabelle, Dumont Bertrand, Lefèvre François, Litrico Isabell. (2015) A social–ecological approach to managing multiple agro-ecosystem services, Current Opinion in Environmental Sustainability, Volume 14, June, Pages 68–75*

[3] *Singh, Preet Pal, (2008), Exploring biodiversity and climate change benefits of community-based forest management, Global Environmental Change 18, 468–478.*

[4] *FAO (2015) The impact of disasters on agriculture and food security, http://www.fao.org/3/a-i5128e.pdf accessed 23 Jan 2017*

Course Outline

Module 1: **Relevance of Disaster and Climate Risk Management for Sustainability of Social Ecological Systems**

This module introduces basic terminology of disaster risk management, climate change science and impacts of climate related disasters on the agriculture sector. It also describes the agro ecosystem as a social ecological system, and Ecosystem based Approaches (EBA) to build their resilience.

Session 1.1.	Basic concepts of Disaster Risk Management (DRM) and Impacts on Agriculture
Session 1.2.	Climate Change and its Impacts with Emphasis on Agriculture Sector
Session 1.3.	Agro-ecosystem as a Social Ecological System, and its Resilience and Sustainability
Session 1.4.	Introduction to Ecosystem based Approaches to build Resilience of Agro-ecosystems
Session 1.5.	(Video screening) Case study- Building Resilience of an Agro-ecosystem

Module 2: **Generation and Application of Weather and Climate Related Information**

This Module provides a discussion of climate information generation, their dissemination and potential applications to build resilience of agroecosystems.

Session 2.1.	Weather and Climate Forecasting, Information Dissemination and their Potential Applications
Session 2.2.	Group work

Module 3: **Planning for Vulnerability Reduction and Resilience Building of Agro-ecosystems**

This Module provides background information for project formulation using accepted approaches and tools such as the Theory of Change, Logframe Analysis and Multi-criteria analysis etc. This will form the basis for the scenario based group work.

Session 3.1.	Project Formulation for Design of Interventions to Build Resilience of Ecosystems
Session 3.2.	Theory of Change
Session 3.3.	Group work on TOC
Session 3.4.	Logical Framework Analysis
Session 3.5.	Group work on LFA
Session 3.6.	Introduction to Cost Benefit Analysis and Multi Criteria Analysis

Module 4: **Synthesis of Learnings through a Scenario Based Exercise**

During this module, participants will apply the learnings from previous modules to develop a climate resilience strategy based on a given scenario suitable for each country context.

Session 4.1. Introduction to Scenario Based Group Work

Group work

Group Presentation to a Panel

Critique

Conclusion

Contents

Module 1

Relevance of Disaster and Climate Risk Management for sustainability of Social Ecological Systems

Session 1.1.
Basic Concepts of Disaster Risk Management (DRM) and Impacts on Agriculture

Learning Objectives

At the end of this session, the participant would be able to:
- Explain selected terms used in Disaster Risk Management.
- Discuss impact of disasters on the agriculture sector, sub sectors of Fishery and Forestry and related livelihods.

1. Introduction to disaster risk management terminology

These terms are generic. Therefore relate them to the agriculture sector as you discuss them.

After any major disaster, the post disaster needs assessment (PDNA) is conducted based on impact on development sectors. FAO (2015)[1] has considered Fishery and Forestry as sub sectors of agriculture in assessing impact of disasters on the agriculture sector.

Therefore in discussing these terms, focus on the agriculture sector. In order to understand the significance of early warning, weather and climate information on the agriculture sector and specific sub sectors, a basic understanding of terminology is important.

Disaster - According to the United Nations International Strategy on Disaster Reduction UNISDR (commonly referred to as ISDR) Terminology 2009, a **Disaster** is a serious disruption of the functioning of a community or society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

Disasters are often described as a result of the combination of: the **exposure to a hazard**; the conditions of **vulnerability** that are present; and insufficient **capacity** or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation

[1]*FAO (2015) The impact of disasters on agriculture and food security, http://www.fao.org/3/a-i5128e.pdf accessed 23 Jan 2017*

A **Hazard** – is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.

Examples of natural hazards are typhoons, earthquake and volcanic eruption, which are exclusively of natural origin. A tsunami is an example of a secondary hazard – a new danger arising due to the impact of a hazard in this case an earthquake. Landslides, floods, drought, fires are socio-natural hazards since their causes are both natural and influenced by human activity.

Human-induced hazards are associated with industries or energy generation facilities and include explosions, leakage of toxic waste, pollution, dam failures. War or civil strife is included in this category.

Hazards can be single, sequential or combined in their origin and effects. For example, an earthquake can cause a landslide, which temporarily dams a river and then causes a flash flood downstream when the temporary dam gives way. A community may be exposed to multiple hazards due to its simultaneous occurrence at the same time.

Climate change is predicted to increase the frequency and level of impact of climate elated hazards i.e. hydro-meteorological hazards such as floods, droughts, cyclones, wild fire, GLOF etc.

Vulnerability - is the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset) which is independent of its exposure. However, in general, the word is broadly used to include the exposure of elements.

Exposure – is the people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Capacity – is the combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals.

Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management. Capacity also may be described as capability. Capacity assessment is a term for the process by which the capacity of a group is reviewed against desired goals, and the capacity gaps are identified for further action.

Disaster Risk – is the potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

The definition of disaster risk reflects the concept of disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped in broader terms.

Disaster risk is often considered as a function of hazard probability, potential loss (assessed using elements at risk) and capacity of the community at risk.

$$\text{Risk} = \frac{\text{Hazard (probability)} \times \text{Loss (expected)}}{\text{Preparedness (or Capacity)}}$$

Some use Vulnerability x Exposure to replace Loss. As vulnerability is sometimes difficult to estimate, potential loss is a more practical criterion to assess risk. Vulnerability and risk increase loss and therefore increase the level of loss.

Loss can be direct which is measurable. Example the cost incurred by the destruction of one kilometer of road and the investment needed to replace it. Some losses cannot be measured in monetary terms. Example is the loss of lives. An example of an indirect loss is malnutrition of children that may result due to the inability or delay in livelihood recovery. Loss estimate is helped by the study of impact on elements at risk described below.

Elements at Risk - this includes who and what can be damaged.

People

Deaths, injury, displacement, health

Physical Assets

Infrastructure

Buildings, Roads, Railway, Bridges, Harbor, Airport etc.

Critical facilities

Emergency shelters, Schools, Hospitals, Fire, Brigade, Police etc.

Utilities

Power supply, Water supply, Transport, Communication, Government services etc.

Economic Assets

Livelihoods

Economic activities (jobs, production facilities and equipment, crops)

The Natural Environment

Natural resources base

Biodiversity

Landscape

Physical and chemical changes in the surrounding

Disaster Risk Reduction (DRR) – The concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

A comprehensive approach to reduce disaster risks is set out in the United Nations-endorsed Hyogo Framework for Action, adopted in 2005, whose expected outcome is "The substantial reduction of disaster losses, in lives and the social, economic and environmental assets of communities and countries." A snapshot of HFA is represented in Figure 1.

It provides a goal, five priorities for action and cross cutting issues. HFA was an initiative for risk reduction from 2005 – 2015.

The Post-HFA initiative is called the Sendai Framework for Disaster Risk Reduction (SFDRR) spanning 2016-2030.

The United Nations International Strategy for Disaster Reduction (UN ISDR) system provides a vehicle for cooperation among Governments, organizations and civil society actors to assist in the implementation of the Framework. Note that while the term "disaster reduction" is sometimes used, the term "disaster risk reduction" provides a better recognition of the ongoing nature of disaster risks and the ongoing potential to reduce these risks.

A snapshot of SFDRR is provided in Figure 2.

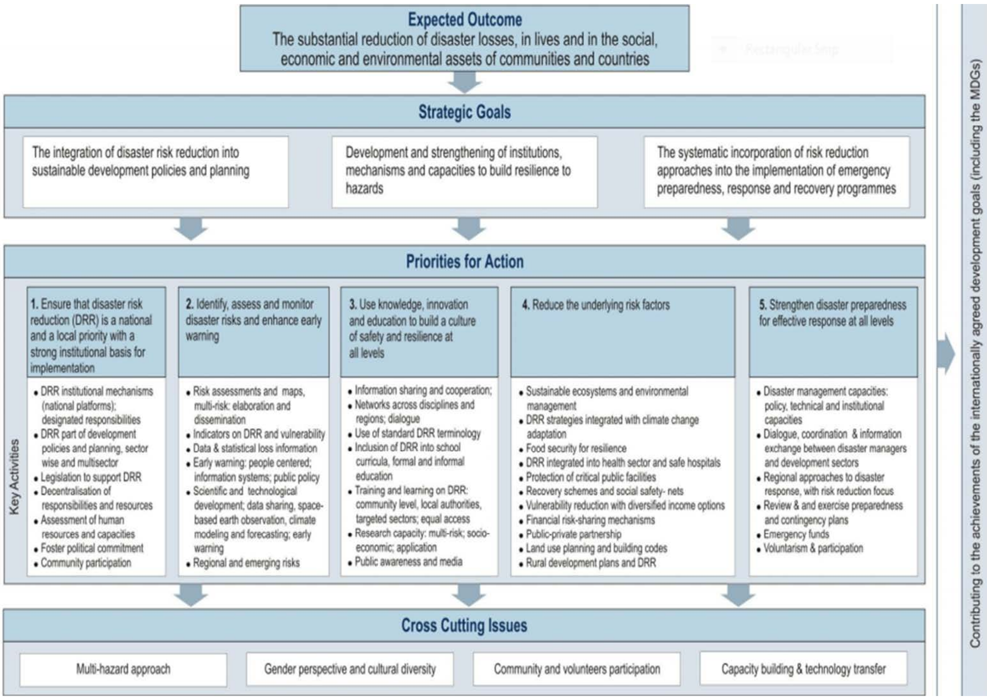

Figure 1: Snapshot of HFA

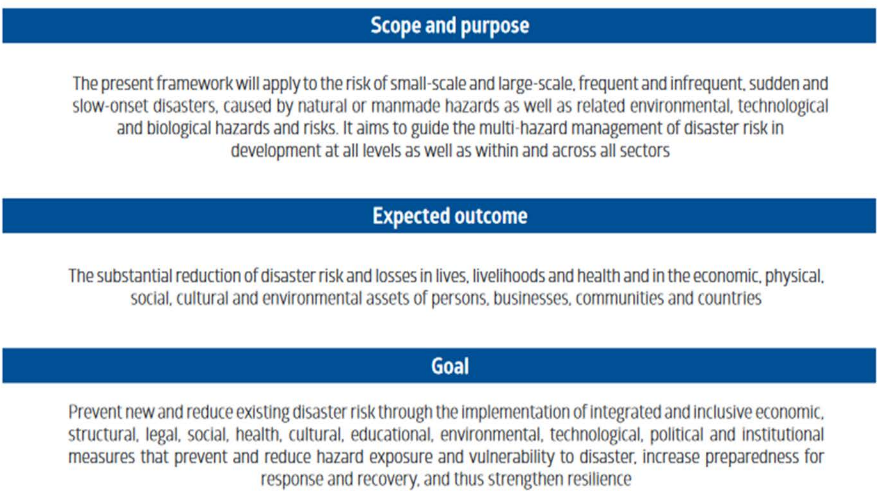

Figure 2-1: Snapshot of SFDRR

Priorities for Action

There is a need for focused action within and across sectors by States at local, national, regional and global levels in the following four priority areas.

Priority 1 Understanding disaster risk	Priority 2 Strengthening disaster risk governance to manage disaster risk	Priority 3 Investing in disaster risk reduction for resilience	Priority 4 Enhancing disaster preparedness for effective response, and to «Build Back Better» in recovery, rehabilitation and reconstruction
Disaster risk management needs to be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment	Disaster risk governance at the national, regional and global levels is vital to the management of disaster risk reduction in all sectors and ensuring the coherence of national and local frameworks of laws, regulations and public policies that, by defining roles and responsibilities, guide, encourage and incentivize the public and private sectors to take action and address disaster risk	Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment. These can be drivers of innovation, growth and job creation. Such measures are cost-effective and instrumental to save lives, prevent and reduce losses and ensure effective recovery and rehabilitation	Experience indicates that disaster preparedness needs to be strengthened for more effective response and ensure capacities are in place for effective recovery. Disasters have also demonstrated that the recovery, rehabilitation and reconstruction phase, which needs to be prepared ahead of the disaster, is an opportunity to «Build Back Better» through integrating disaster risk reduction measures. Women and persons with disabilities should publicly lead and promote gender-equitable and universally accessible approaches during the response and reconstruction phases

Figure 2-2: Snapshot of SFDRR

The SFDRR presents 7 targets showing the way "how" to reduce risk shown below.

- **7 targets**

Substantially reduce :

1. disaster mortality by 2030, aiming to lower average per 100,000 global mortality between 2020-2030 compared to 2005-2015.
2. the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020-2030 compared to 2005-2015.
3. direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.
4. disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.

Substantially increase :

5. the number of countries with national and local disaster risk reduction strategies by 2020.
6. international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030.
7. the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

- Developing indicators in conjunction with SDGs
- Climate change identified as a one of drivers of disaster risk

AADRR

Figure 3: Targets of SFDRR

Disaster Risk Management (DRM) - is the systematic process of using administrative decisions, organizations, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters.

This comprises activities including structural and non-structural measures to avoid (prevention), to limit (mitigation and preparedness) or transfer adverse effects of hazards (risk insurance). Risk management is the process of implementing structured and systematic processes and procedures for examining risks and for making decisions based on them.

Figure 4 below represents the DRM process graphically. It looks at the pre-disaster, response (during) and post-disaster as three phases in a cycle and depicts the activities that needs to be carried out during each stage.

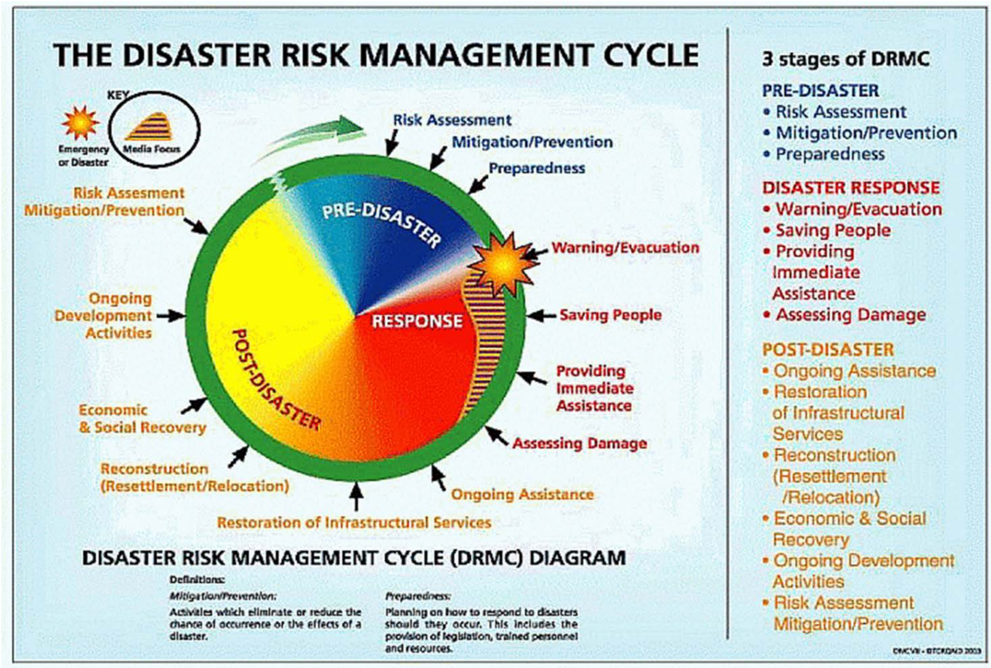

Figure 4: Detailed Disaster Risk Management Cycle

One criticism that has been levelled at this Framework is that the inclusiveness of the community is not reflected in the diagram.

According to www.torqaid.com, (2002 updated 2011) the Disaster Risk Management Cycle (DRMC) is a continuum, consisting of three stages as follows:

- Risk Reduction Continuum
- The Emergency Response
- Post Disaster Continuum

Figure 5 below illustrates these three stages as a continuum.

The final components relating to effective DRR are the ten key DRM Initiatives summarized below. Crucially, all of these initiatives or issues should ideally be addressed in the Normal/Risk Reduction Stage of the DRMC – i.e. before a potential disaster is faced.

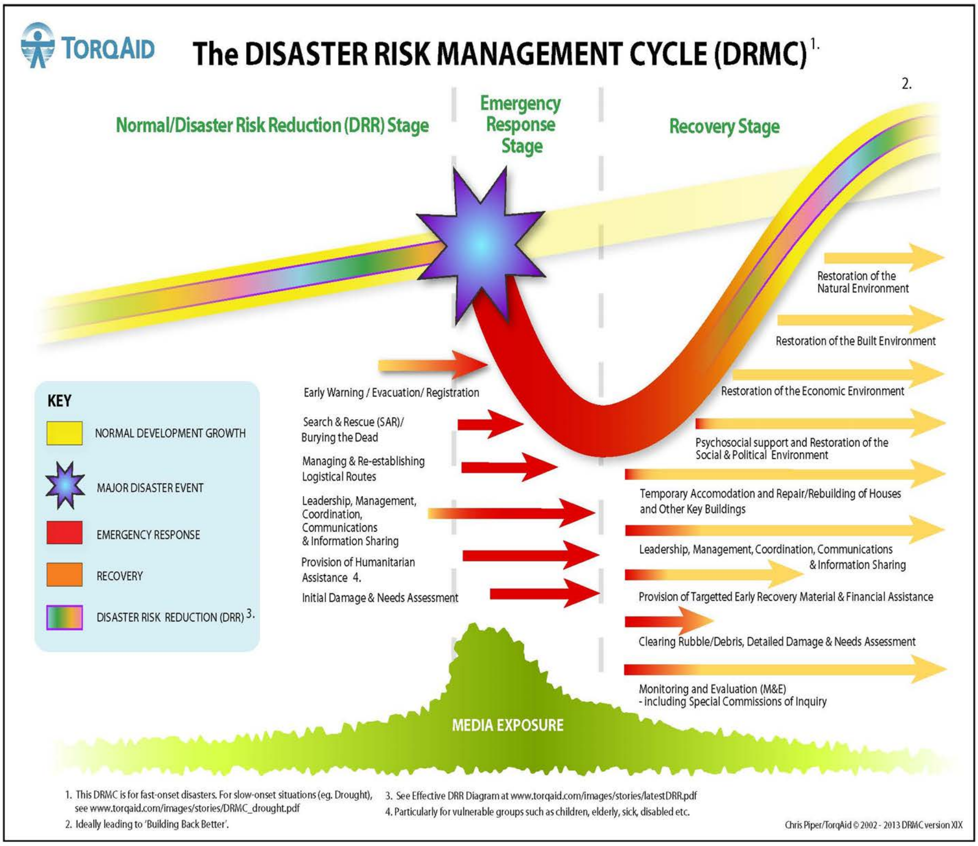

Figure 5: Disaster Risk Management Cycle / Continuum

- Advocacy, Policy & Legislation
- DRM (including DRR) Funding
- Organizational Structures, Coordination Mechanisms, Management, and Leadership
- Risk Management Process
- DRM Planning at all levels
- Capacity Building & Training
- Research & Information Management
- Early Warning Systems & Possible Evacuation
- Public Awareness & Education
- DRM/DRR Monitoring & Evaluation (M&E)

2. The impact of disasters on agriculture

This section relies substantially on the FAO Report "The Impact of disasters on Agriculture and Food Security" (2015)[2]. It is the latest synthesis avaiable and is gratefully acknowledged. The Report has analyzed 140 medium- and large-scale disasters (affecting at least 250 000 people) that occurred in 67 developing countries between 2003 and 2013. The basis for selection has been that such disasters are likely to impact agricultural production at the national level and can be analyzed using national statistics.

The assessment has found that approximately USD 80 billion was lost as a result of declines in crop and livestock production after these disasters. The report corresponds this loss to an equivalent of 333 million tons of cereals, pulses, meat, milk and other commodities.

The threat to food security at household level would have been very significant.

Figure 6 below depicts the direct physical damage, losses, and damage and loses to the agriculture sector as a percentage of the total damage and losses of the disasters considered in the analysis.

Figure 6: Percentage Impact on Agriculture Sector (Source: Adopted from http://www.fao.org)

Figure 7 below depicts imacts by disaster type. Most damage and losses caused by droughts is to agriculture. Storms and floods also have a considerable impact while geological disasters appears to have only a low-level impact.

[2]*http://www.fao.org/3/a-i5128e.pdf accessed 23 Jan 2017*

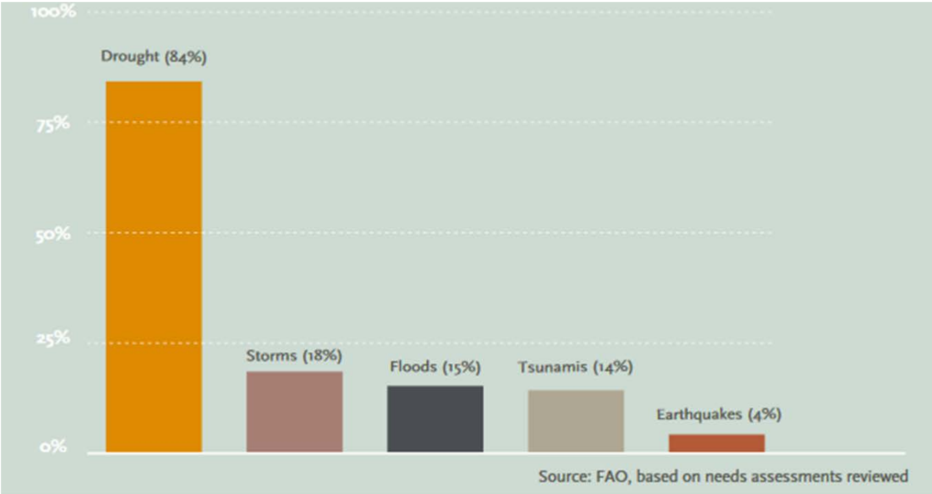

Figure 7: Damage and losses to the agriculture sector by type of hazard (percentage share of all sectors combined) (Source: Adopted from http://www.fao.org/3/a-i5128e.pdf)

These data apparently do not include impact on farm-employment and livelihood disruption.

3. Impact on Agricultural Sub Sectors

Figures 8 (a) and (b) depict damage and losses to agricultural sub sectors.

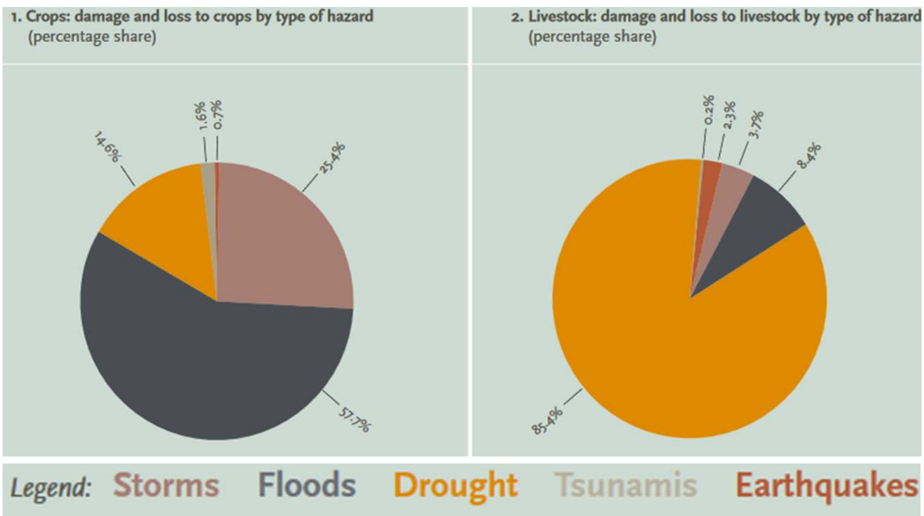

Figure 8: (a) Damage and losses to agriculture subsectors of crops and Livestock by type of hazard (Source: Adopted from http://www.fao.org/3/a-i5128e.pdf)

Crops and livestock impacts appear to be more from droughts, floods and storms.

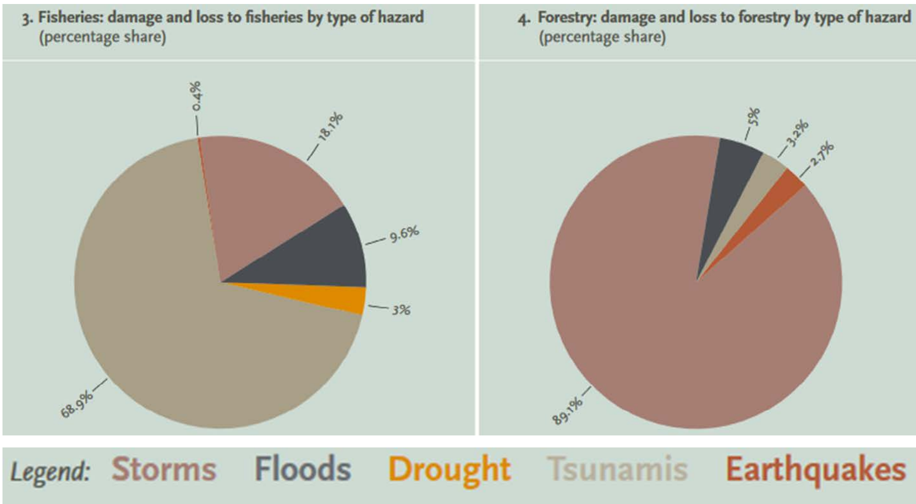

Figure 8(b) Damage and losses to agriculture subsectors of fisheries and forestry by type of hazard (Source: Adopted from http://www.fao.org/3/a-i5128e.pdf)

The fisheries subsector appears relatively more affected by tsunamis and storms while most of the economic impact to forestry appear to be caused by floods and storms.

4. Wider Implications of Disaster Impact

Direct damage and losses would include damage to crops, seed stock, agricultural infrastructure, transport routes, and natural resources that support agriculture. It will bring fatalaties and diseas to livestock. It may also involve depletion of grain reserves. With damage to cropland and livestock, the value chains involving agro suppliers, processors of agro products and finacial cash flow constraints will bring cascading impacts. Manufacturing industries for food and non-food agro products will be impacted leading to macro-economic repercussions.

At household and community levels, loss of income and livelihoods escalation of food prices, decrease in small loans from retailers due to decreased income level of farmers etc. will create sociological repercussions.

These add up to implications on sustainable growth.

Figure 9 below depicts them graphically as cascading impacts.

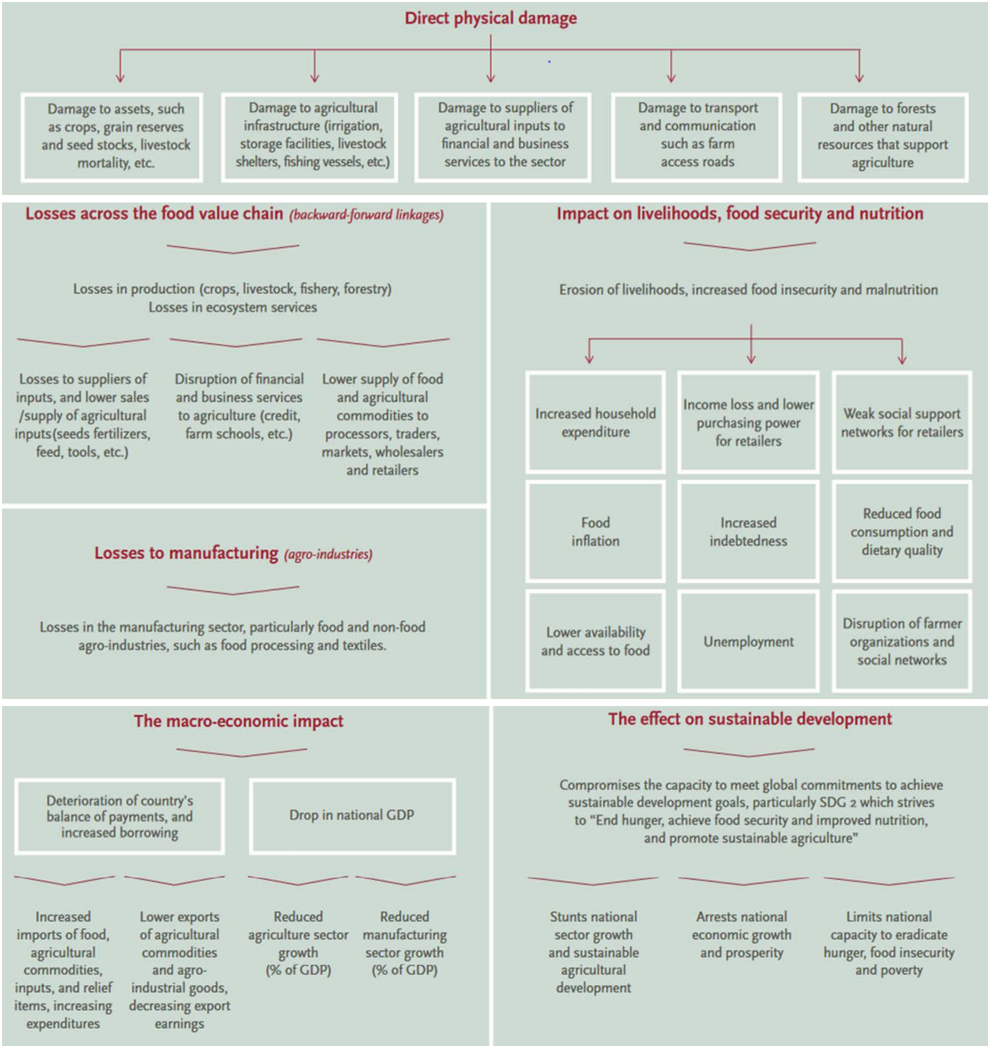

Figure 9: Cascading Impacts of Disasters (Source: Adopted from http://www.fao.org/3/a-i5128e.pdf)

5. Case Study

Thailand Floods 2011

Severe flooding occurred during the 2011 monsoon season in Thailand. The flooding began at the end of July triggered by the landfall of Tropical Storm Nock-ten. These floods soon spread through the provinces of northern, northeastern, and central Thailand along the Mekong and Chao Phraya river basins. In October floodwaters reached the mouth of the Chao Phraya and inundated parts of the capital city of Bangkok. Flooding persisted in some areas until mid-January 2012.

It resulted in a total of 815 deaths (with 3 missing) and 13.6 million people affected. Sixty-five of Thailand's 77 provinces were declared flood disaster zones.

The disaster had been described as "the worst flooding in terms of the volume of flood water and people affected."

The World Bank has estimated 1,425 trillion baht (US$46.5 billion) in economic damages and losses due to flooding, as of 1 December 2011[3]. Much of this was due to impacts on industrial sites. Over 20,000 square kilometers of farmland was damaged[4]. In Thailand 16 million people are rice farmers[5] and the flood forced their livelihood into disarray. The loss to the agriculture sector has been put at 1.3 billion Bhat[6]. This was nearly 3% of the total damage and losses. However this loss dethroned Thailand from No1 ranked global Rice Exporter. Nearly 25% of the rice crop did not survive the floods[7]. Its struggle to reach the top again has run into serious trouble due to the decade-worst drought caused by the 2015 El Nino. Thailand's rice production fell by 15-20%[8]. Thailand's rice export prices continued to decline 5% to 6% due to competition from Vietnamese rice, which is reportedly cheaper as its new-crop supplies are entering the market.

The impacts of the 2011 flood is depicted in the Figure 10 below reflecting macro economic impacts also contributed to by the agriculture sector.

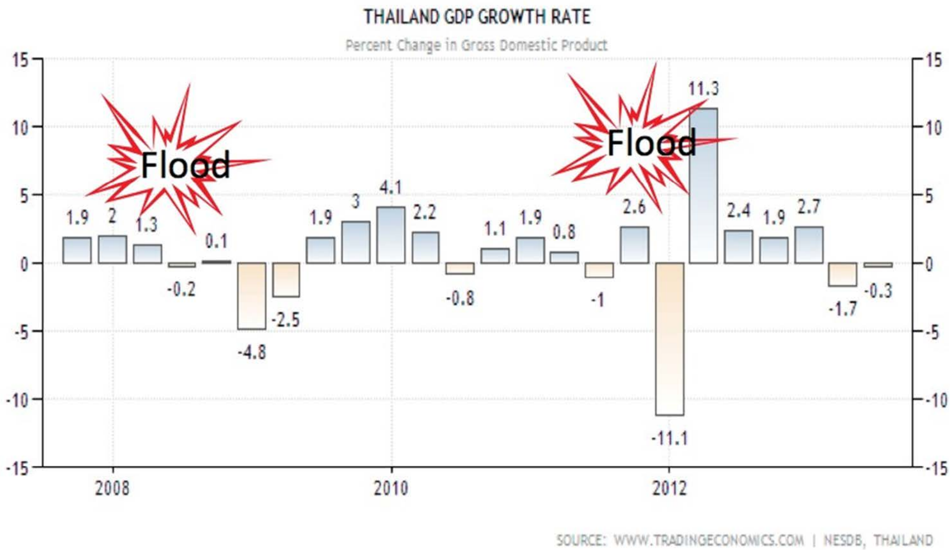

Figure 10: Impact of 2011 Flood on thailand's GDP

[3]Haraguchi, Masahiko; Lall, Upmanu (December 2015). "Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making" (PDF). International Journal of Disaster Risk Reduction. 14 (3): 256–272. Retrieved 6 October 2016
[4]Flood, storm and landslide situation report)" (PDF) (in Thai). 24/7 Emergency Operation Center for Flood, Storm and Landslide. 17 January 2012. Retrieved 25 January 2012
[5]"The Rice Mountain". The Economist. 2013-08-10. Retrieved 30 September 2016
[6]http://www.fao.org/3/a-i5128e.pdf
[7]Breakingnews.nationchannel.com. Retrieved 15 November 2011
[8]Bangkok Post, Jul 22, 2015

Session 1.2.
Climate Change and its Impacts with Emphasis on Agriculture Sector

Learning Objectives

At the end of this session, the participant would be able to:

- To explain the concept of Climate Change (CC) and its causative factors.
- To discuss projected impacts due to climate change
- To describe potential impacts on agro-ecological systems
- To discuss the global interventions related CC

1. Introduction to the terminology

The definitions of terminology are adopted from UNISDR and IPCC.

Weather: Weather is the state of atmosphere at a given time and place measured in terms of variables that include temperature, precipitation, cloudiness, humidity, air pressure and wind. Weather may change over the course of a day, and from one day to the next; it might be warm and dry today, but cooler and wet tomorrow. Equally, weather may differ between places which are geographically relatively close; for example, on a given day, one village might experience rain while another village 50 miles away does not.

Climate: Climate is the long-term average of conditions in the atmosphere described by statistics, such as means and extremes. Thus, the climate represents average weather conditions for a place over a long time period (several decades) as described by statistics such as the mean and variability of the elements of weather mentioned previously. Thus, the climate represents prevailing weather conditions over a long time period. The Figure 1 below provides the climatic regions for the world.

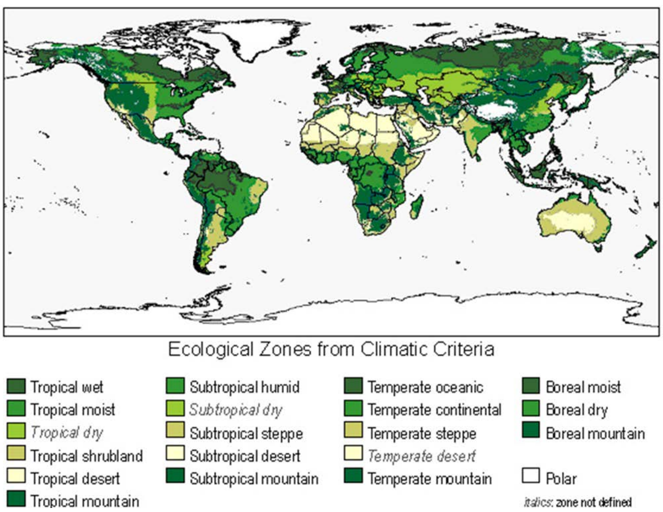

Figure 1: Ecological zones from Climatic Criteria (Global Forests Resources Assessment 2000 (FAO, 2001))

The climate of a given area is determined by factors including its latitude (distance from the equator), altitude, terrain, proximity to the ocean or other bodies of water, land cover and ocean currents. On a regional scale, areas with consistent climates form climate regions as shown in the Figure. Climate regions are differentiated on the basis of means and variation in components of weather such as temperature and precipitation.

Season: Seasons are annually recurring periods differentiated by weather, daylight hours and ecology. Seasons result from changes in the intensity of solar radiation (energy from the sun) received by an area over the course of a year, and from knock on effects (or feedbacks) in the Earth's climate system which result from these changes.

Different areas of the world experience seasons differently. Far from the equator, temperate and Polar Regions experience spring, summer, autumn and winter. In the tropics, many regions experience wet and dry seasons, monsoons and wind cycles.

Climate variability: Climate variability refers to fluctuations in the mean state. It refers to natural changes in climate which fall within the normal range for that particular region. For example, some years will be wetter than others, some summers will be unusually dry, and some years will be hotter and others colder. The Figure 2 below illustrates these fluctuations. Anomalies are marked by blue bars. The normal range (upper & lower) for that area is marked by the red lines.

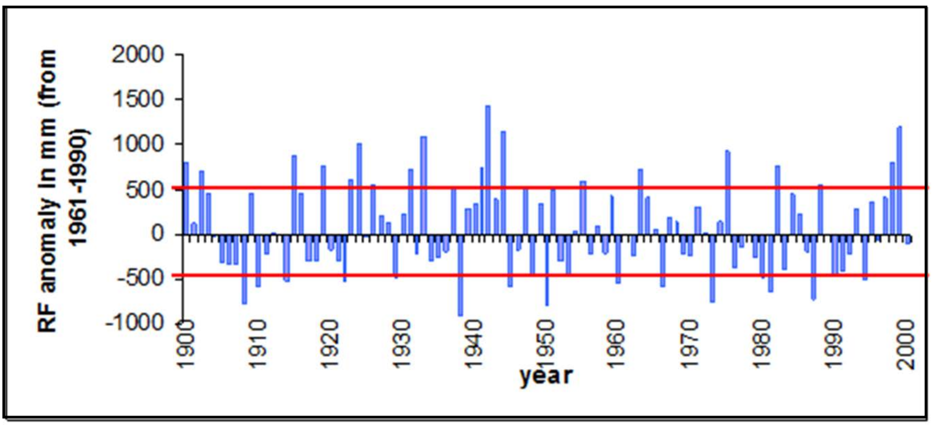

Figure 2: Normal Range for Annual Rainfall Anomaly of a hypothetical geographical region

When the anomaly exceeds the upper or lower normal range it is called and extreme climate event. These extreme events are rare but have occurred across timelines of many geographical regions.

According to the World Meteorological Organization (WMO), climate is typically defined in terms of 30-year means called the climatic averaging period, with variations observed about the mean called the range. This implicitly assumes a consistency of a given climate state over a particular region. On the shortest time scales of a few days, we get weather forecasts.

The following graphs (Figure 3 and 4) illustrates the impacts of increase in mean temperature on changes of weather patterns.

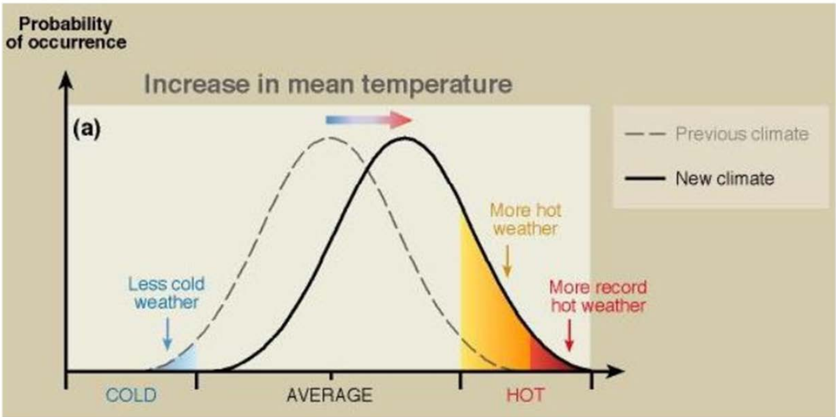

Figure 3: Predicted Impacts From a Shift of Mean Temperature (Source: IPCC)

Such shifts are already being experienced in different parts of the earth. These are also manifested in daily minimum and maximum temperatures.

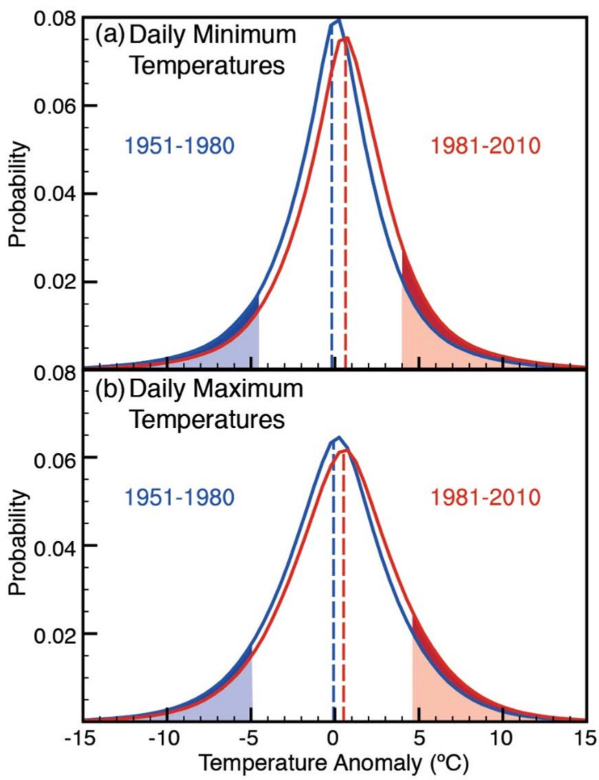

Figure 4: Impact of Temperature Anomaly of the Mean Temperature on the Daily Minimum and Maximum

Climate change: According to IPCC, climate change refers to a statistically significant variation in either the mean state of the *climate* or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or *external forcings* (solar variations and explosive volcanism), or to persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*.

Note that the *United Nations Framework Convention on Climate Change (UNFCCC)*, in its Article 1, defines "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between "climate change" attributable to human activities (anthropogenic) altering the atmospheric composition, and "climate variability" attributable to natural causes. Climate change includes changes to temperature, rainfall patterns and characteristics, wind regimes, or ice cover. Archaeological, geological and historical records indicate many long-term and short-term changes in the climatic history of the Earth. Figure 3 below shows that temperature anomaly had persisted as an increasing trend since mid-1940s, which is over the 30 year period of climatic averaging period. This trend is therefore a climate change.

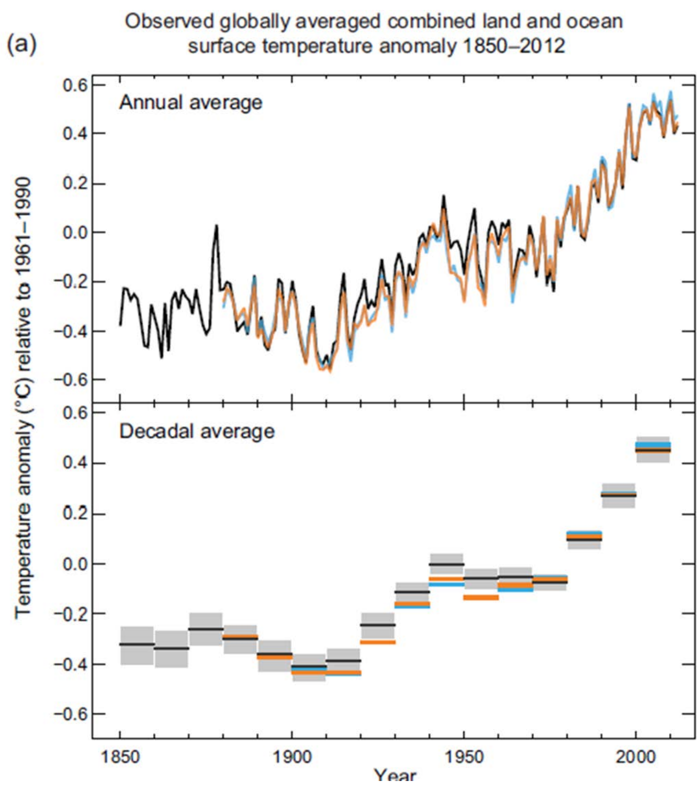

Figure 3: Changes in global mean annual temperature 1880-2012 (Source: AR5 2014) [Blue columns are differences respect to the 1951-1980 global average and the red line is a smoothed five-year running mean of the anomalies.]

ISDR comments that for disaster risk reduction purposes, either of these definitions may be suitable, depending on the particular context. The UNFCCC definition is the more restricted one as it excludes climate changes attributable to natural causes. The IPCC definition can be paraphrased for popular communications as "A change in the climate that persists for decades or longer, arising from either natural causes or human activity."

2. The Earth's Energy Budget

- To understand climate change, it is necessary to understand how the earth's warmth is controlled.
- The ultimate source of energy on Earth is the Sun.
- The energy from the Sun reaches the top of our atmosphere in the form of light. It sustains the climate system, (made up of earth's water, ice, atmosphere, rocky crust, and all living things[2]).
- The plant life and microscopic plants in fresh and marine waters (phytoplankton) that contain the pigment chlorophyll are the primary producers of food by converting carbon dioxide and water into sugar using light energy.
- Living beings use the food for their energy by burning (oxidizing with oxygen O_2) the sugar and releasing heat and carbon dioxide back to the atmosphere. Primary producers give rise to food chains that sustain life in ecosystems. Ecosystem services nurture human societies.
- Ancient plants that got fossilized are the sources of fossil fuel such as coal and crude oil. By burning fossil fuel, we release carbon dioxide and heat back to the atmosphere.

The Greenhouse Effect[3]

- Energy coming as short wavelength from the sun to the top of the atmosphere is measured in Watt per square meter per second (Watts/m2) which is about 1350. Measurements are done through satellite.
- Not all the energy at the top of the atmosphere reaches the Earth's surface.
- Clouds, gases and aerosols (fine solid particles in the air, like dust or soot) reflect a third of incoming solar radiation.
- Almost a quarter is absorbed (captured) by atmospheric gases and particles.
- Nearly half of the incoming solar energy reaches the earth's surface and is absorbed and converted to heat that raises its temperature.
- This heat energy is distributed throughout the five components of Earth's climate system. This heat is redistributed for evaporation of surface water, evapo-transpiration by plants, convection, facilitate precipitation, formation of winds, and ocean circulation (See Figure 1). During these processes, long wave length thermal radiation (infra-red rays) is emitted by the land and the ocean.
- To balance the absorbed incoming energy, the Earth must, on average, radiate the same amount of energy back to space.

- However over a long period of time, there is a balance left and it is this energy balance that maintains the mean global surface temperature of the earth.
- This balance is brought about by absorption of the thermal radiation by the atmospheric gases, including clouds, and re-radiated back to Earth. This is called the **greenhouse effect**[4].

It is called the greenhouse effect because the glass walls in a greenhouse reduce airflow and increase the temperature of the air inside (See Figure 2). Analogously, but through a different physical process, the Earth's greenhouse effect warms the surface of the planet. Green houses retain the heat by trapping the heated air within the glass walls. The atmospheric gases do it by absorbing outgoing heat and re-emitting it back to the earth.

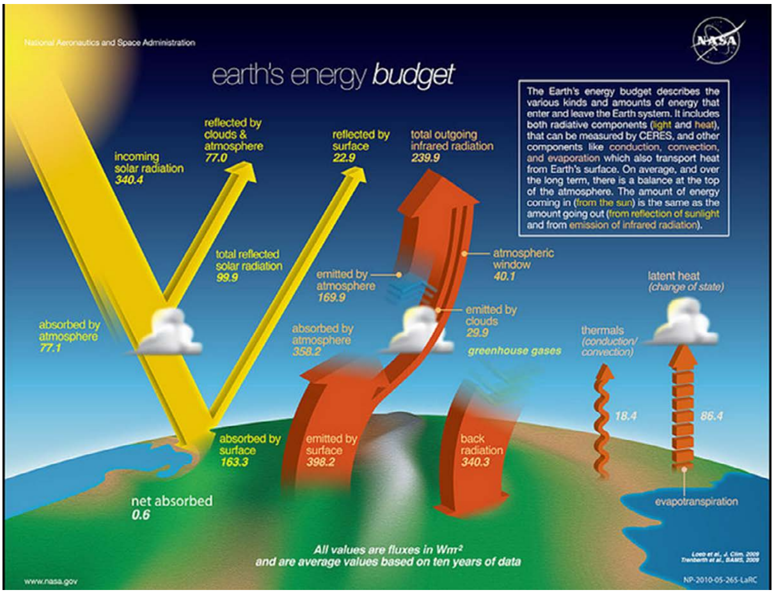

Figure 1: Energy Budget of the Earth

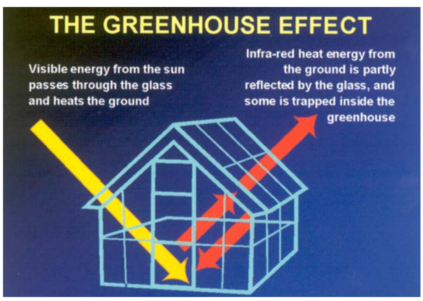

Figure 2: Graphical Representation of Green House Effect

[2]*AR4 SYR Synthesis Report Annexes. Ipcc.ch. Retrieved on 2011-06-28*
[3]*http://science-edu.larc.nasa.gov/energy_budget/ quoting Loeb et al., J. Clim 2009 & Trenberth et al, BAMS 2009, Public Domain retrieved 26th Jan 2017*
[4]*https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html*

The Green House Gases (GHGs)

The gases that absorb and trap this heat are called *greenhouse gases (GHGs)*.

According to IPCC, greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic (man-made), that absorb and emit radiation emitted by the Earth's surface, the atmosphere, and clouds.

If not for the greenhouse effect and the balance of energy left on earth due to it, the earth would be about 30°C colder and would be uninhabitable. This is a natural phenomenon.

Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover there is a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) are man-made chemicals through industrial processes.

Water Vapour - Although the total quantity of water in the atmosphere is nearly constant, the local moisture content (humidity) varies greatly in time and space. Also, as water vapor condenses and precipitates as rain therefore average residence time of water in the atmosphere amounts to just 10 days. (See Figure 3)

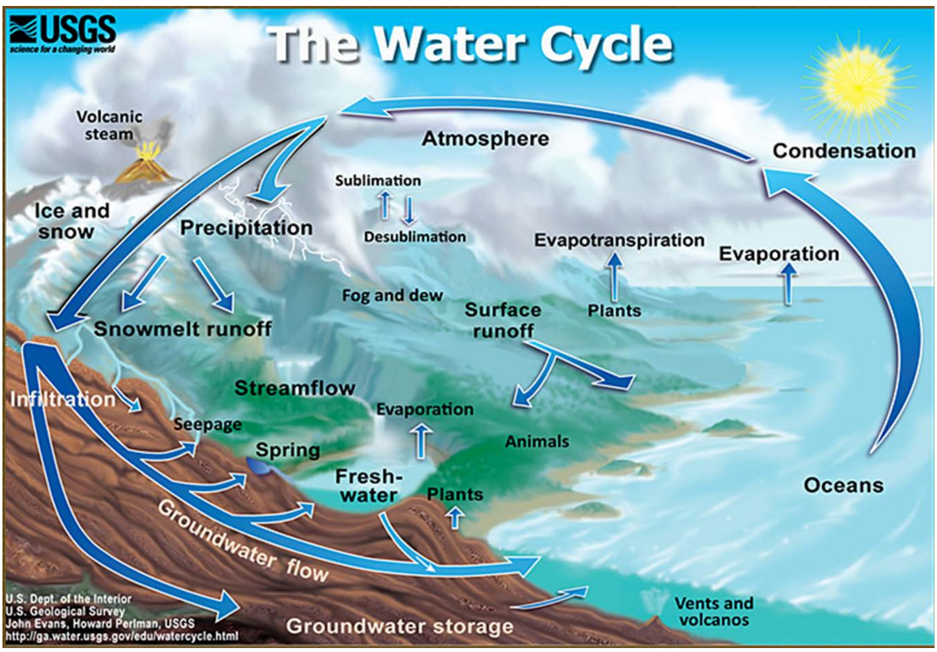

Figure 3: The Water Cycle

Carbon Dioxide: CO_2 is a product of combustion and respiration. Since the beginning of the industrial revolution some 200 years ago, human societies have emitted increasing amounts of CO_2 to the atmosphere, significantly raising its atmospheric concentration to about 400 parts per million (ppm) today. For instance, grams per ton are parts per million. Carbon cycle given in Figure 4 illustrate the cyclic movement on earth.

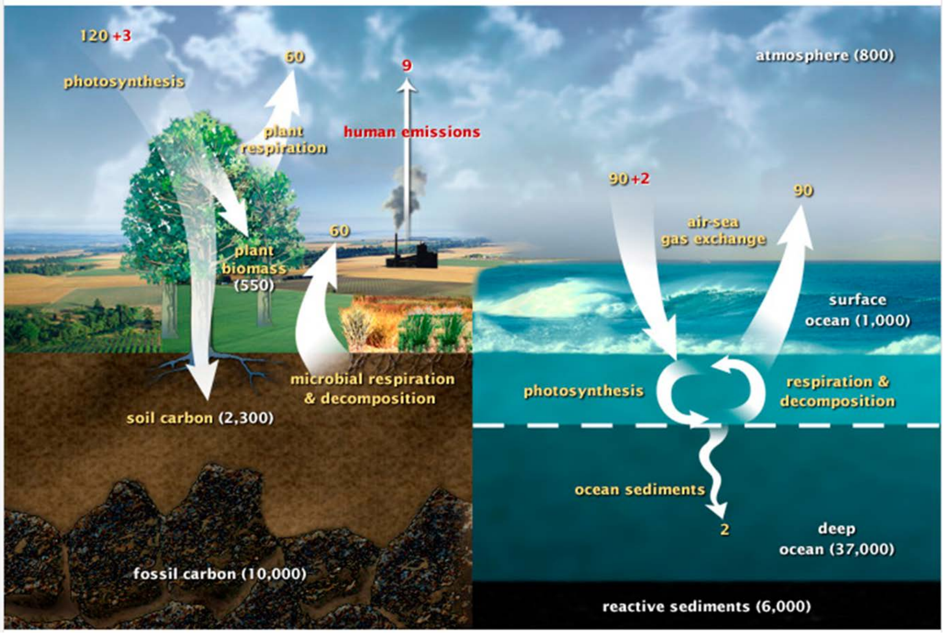

Figure 4: Carbon Cycle (This diagram of the fast carbon cycle shows the movement of carbon between land, atmosphere, and oceans. Yellow numbers are natural fluxes, and red are human contributions in gigatons of carbon per year. White numbers indicate stored carbon. (Diagram adapted from U.S. DOE, Biological and Environmental Research Information System.))

Methane: CH_4 concentration in the atmosphere is some thousand times smaller, approximately 4 gigatons. CH_4 forms during anaerobic fermentation processes by certain microbes that thrive in environments such as wetlands, paddies, sewage and stomachs of ruminants.

Nitrous Oxide: N_2O sources are the production of industrial fertilizers, bio fuel combustion and soil microbial activity. It atmospheric concentration is approximately half of methane's.

Ozone: Ozone present in the troposphere below 10 km from the earth's surface, are created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapours, and chemical solvents are some of the major sources of NOx and VOC. Ozone is very reactive and its life time is relatively very small.

Ozone in the stratosphere, absorbs sun's ultraviolet radiation and heat dissipated in the lower atmosphere. This can generate heat. But reduction in stratospheric ozone due to the pollutants can lower temperatures. Observations for last few decades show the mid to upper stratosphere (from 30 to 50 km above the Earth's surface) has cooled by 1° to 6° C (2° to 11° F). This stratospheric cooling has taken place at the same time that greenhouse gas amounts in the lower atmosphere (troposphere) have risen. The two phenomena may be linked.[5]

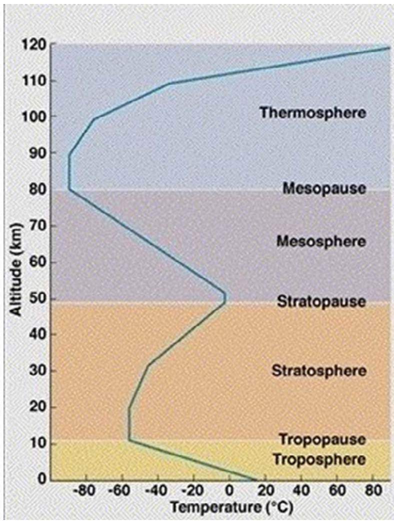

Figure 5: Layers of the Atmosphere (Source: http://www.weather-climate.org.uk/02.php)

Other GHGs in low concentrations

In contrast, the other GHGs remain over the atmosphere a long period, ranging from over a decade for methane to over several decades of time. These are compounds found in relatively low concentrations but high warming potential. Examples are halocarbons, Nitrogen trifluoride and Sulphur hexafluoride. Such long residence times allow them to be thoroughly mixed and exert their effect (forcing) globally. Life time and sources of GHGs are given in Table 1 below.

GHG	Source of Emission	Life Time	Global Warming Potential (GWP[6]) compared to CO_2
Carbon Dioxide	Fossil Fuel burning, Land use changes	100 yrs.	1
Water vapour	See the water cycle in Fig. 3.	Does not decay as it is re-cycled	Difficult to assess as it has broader absorption bands than CO_2
Methane	Natural gas production From wetlands, paddies, sewage, stomachs of ruminants.	10 yrs.	21

Nitrous Oxide	Combustion of bio-fuels	150 yrs.	310
Chlorofluo-rocarbons	Refrigeration and air conditioning systems Fire extinguishers. Now controlled due to the Montreal Protocol.	100 yrs.	8000+
Ground level Ozone	Created by chemical reactions in the atmosphere.	Hours / days	Not available
Nitrogen trifluoride (NF_3)[7]	Man-made during manufacture of many electronics	100 yrs.	17200
Sulphur hexafluoride	Man-made chemical used as an electrical insulator and in the production of magnesium, semiconductors, etc.	3000 yrs.	34900

Table 1: Properties and sources of GHGs (Source: Adopted from IPCC)

Radiative Forcing

According to IPCC, *"Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Radiative forcing values are for changes relative to preindustrial conditions defined at 1750 and are expressed in Watts per square meter (W/m2)."*

Earth's energy balance depends on many factors, such as atmospheric composition (mainly aerosols and greenhouse gases), the albedo (reflectivity) of surface properties, cloud cover and vegetation and land use patterns.

Aerosols: According to NASA[8], "Aerosols have a two-fold cooling effect on climate. In the open atmosphere, they scatter and absorb incoming solar radiation, thereby reducing the amount of sunlight that reaches the surface. Moreover, aerosols act as "seeds"—called cloud condensation nuclei. When clouds form in the polluted atmosphere, the clouds' droplets tend to be smaller and more numerous. Because polluted clouds are typically comprised of more densely-packed droplets, they are more efficient at absorbing and reflecting sunlight, again having a cooling effect on the surface."

[5]*https://www.giss.nasa.gov/research/features/200402_tango/*
[6]*Global Warming Potentials (GWPs) are a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. (IPCC 1996). Carbon dioxide (CO2) was chosen by the IPCC as this reference gas and its GWP is set equal to one (1). GWP values allow you to compare the impacts of emissions and reductions of different gases.*
[7]*AR4 (2007)*

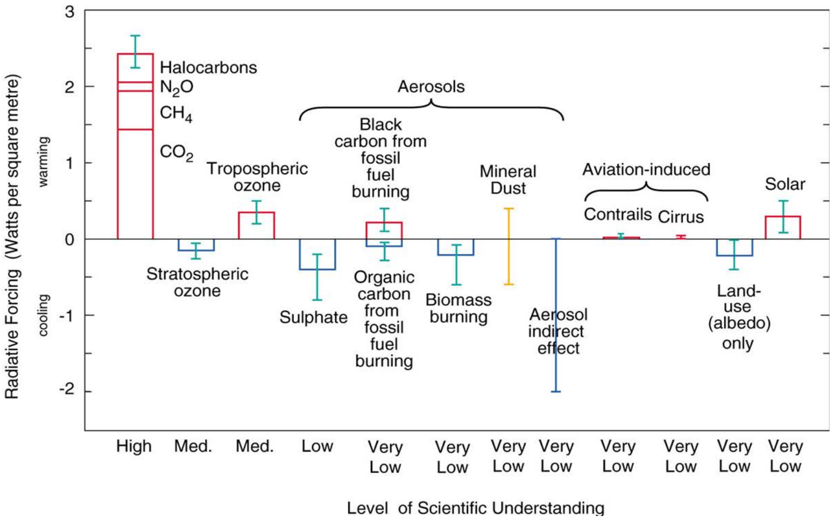

Figure 6: The global mean radiative forcing of the climate system for the year 2000 relative to 1750 (Source: IPCC)

Aerosols are released through human activities, such as burning of biomass or fossil fuels (as soot) and through natural events such as volcanic eruptions.

The phenomenon of cooling or reduction of solar energy reaching the earth due to the influence of aerosols is called **Global Dimming**. There is a school of thought that suggest global warming would have been higher today if not for global dimming.

Albedo: It is the percentage of *solar radiation* reflected back to outer space by surfaces on earth or objects, often expressed as a percentage. Snow and ice have a high albedo. Soils surfaces show variable albedo while vegetation canopy and oceans have a low albedo. Thus albedo varies depending on cloudiness, snow, ice, leaf area and land cover change.

Carbon sinks: These are mainly the photosynthetic plants. Forests and aquatic plants and oceanic phytoplankton (microscopic plants) contribute to absorb carbon dioxide through photosynthesis and act as significant sinks.

Land Use: Altering land cover, to replace forests with cultivated lands can change the albedo level. Croplands and grasslands reflect more light than forests. This contributes to a small magnitude of cooling. Changes in land cover may have an impact on the evapotranspiration by plants and thus affect the hydrological cycle.

[8]*http://earthobservatory.nasa.gov/Features/GlobalFire/fire_4.php*

3. Impacts of Climate Change

These predicted impacts have been adopted from IPCC Assessment Reports.

The positive anomaly of annual global mean temperature (currently thought to be +0.8°C) (See Figure 7), will influence the natural range of temperature fluctuations in different parts of the earth differently and in turn influence the range of climate variability that have been observed in the past. It is predicted to increase the frequency of hydro-meteorological hazards (floods, droughts, cyclones, coastal floods, tornados, wild fires, etc. and associated secondary hazards such as landslides, waterborne diseases etc.), and exacerbate their impacts. Many sectors will be affected. Extreme climate events are predicted to increase their frequency (See Figure 7 & 8). Figure 9 represents available loss data from extreme events.

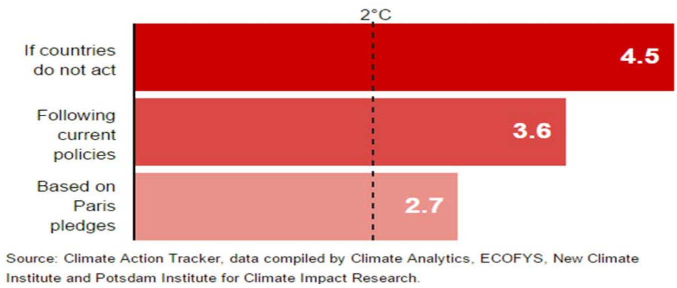

Figure 7: Average Warming Anomaly (⁰C) Predicted by 2100

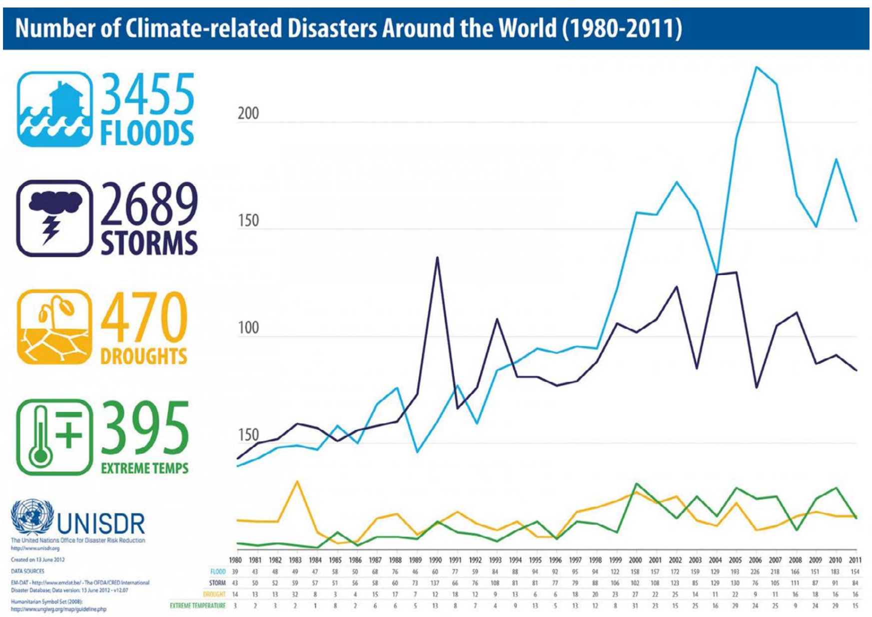

Figure 8: Number of Climate Related Disasters 1980 - 2011

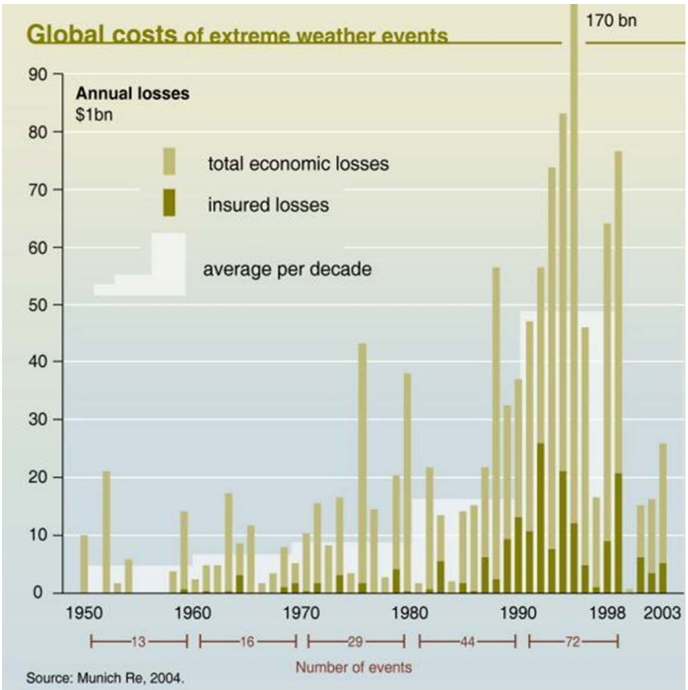

Figure 9: Cost of Extreme Climate Events 1950 - 2003

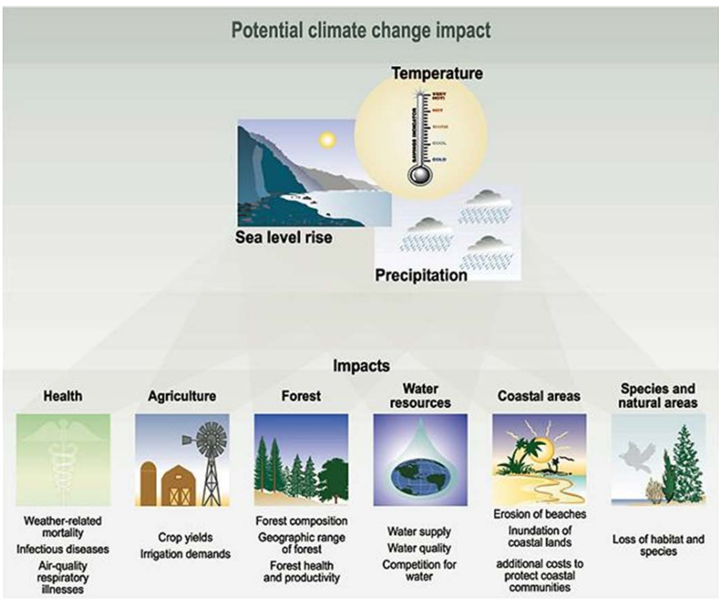

Figure 10: Impacts of Climate change on different sectors

Sea Level Rise and Sea Surface Temperature Increases

According to IPCC, temperature increases affect global sea level through thermal expansion of the oceans and melting of ice caps, glaciers and polar ice etc. In connection with sea level, expansion refers to the increase in volume (and decrease in density) that results from warming water. A warming of the ocean leads to an expansion of the ocean volume and hence an increase in sea level. Global sea level has been rising at an average of 3.2 mm per year since the early 2000s, what would yield a global sea level rise of 16 cm by 2050.

This rise will not be even across the global coastline and may be influenced by other drivers such as land subsidence. Salinity intrusion into surrounding arable land as well as upstream of rivers, will decrease agricultural production of crop varieties and may also contaminate drinking water sources. The oceans have been absorbing much of the extra heat forced by GHGs. This may have consequences of influencing sea surface temperatures that play a primary role in the development of tropical cyclones and monsoon depressions leading to extremes of precipitation and wind impact Increasing surface temperatures can cause coral to bleach[9] and ultimately die. Moreover, increased atmospheric CO_2 concentrations results in acidification of sea water, which in turn have important negative impacts on calcifying organisms, such as corals. As coral reefs are highly productive primary producers of food and provide beginning points for many marine food chains, fish harvest may deplete as a consequence of these impacts on corals.

Melting of Glaciers: Settlements in mountainous regions in the vicinity of glaciers which depend on snow-pack water supplies will discover their water supply decreasing due to receding glaciers. In high mountain tops, glaciers may melt and the melt will accumulate in valleys as glacial lakes. If they breach at weak points, the water would create devastating flash floods called Glacial Lake Out Flow (GLOF) which may impact human settlements downhill.

Biodiversity: Change of temperature regimes and melting of glaciers will create unfavorable conditions for many plant and animal species and create a threat of extinction. With increasing temperatures species are exhibiting changes of habitat ranges. Species are moving to higher elevations expanding their range. For others movement may be into less hospitable habitats[10]. This will change species composition of natural ecosystems threatening their sustainability which may lead to negative influence on their provision of ecosystem services (to be discussed in a later session)

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[9]Bleaching is the result of coral colonies losing their symbiotic photosynthesizing organisms if elevated surface temperatures persist over a threshold number of days. As the coral symbionts account for 80% of their nutritional requirements, bleached colonies have very high mortality rates. Corals that have lost their symbionts look whitish and hence the name bleaching.

[10]USGCRP (2009). Global Climate Change Impacts in the United States. "Climate Change Impacts by Sectors: Ecosystems." Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). United States Global Change Research Program. Cambridge University Press, New York, NY, USA.

to human settlements. Ecosystem services are ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are:

(i) supporting services such as productivity or biodiversity maintenance
(ii) provisioning services such as food, fish, fiber, or timber
(iii) regulating services such as climate regulation or carbon sequestration
(iv) cultural services such as tourism or aesthetic appreciation[11].

Vectors of diseases and pests may find changing temperatures more suitable which will increase their numbers affecting health of humans and livestock and decrease crop yields. Many invasive species may become abundant with undesirable consequences.

4. Predictions of Climate Change Impact

Climate change impacts are expected several decades into the future when the positive anomaly of annual mean global temperature rises beyond 1.5^0 to 2^0 Centigrade, although currently signs of its manifestation are already observed. As looking into the future is not a possibility, assumptions are made and climate modelling is carried out to forecast potential impacts.

Climate models are computer-based simulations that use mathematical formulas to re-create the chemical and physical processes that drive Earth's climate. According to WGII AR5 Glossary, a **Climate Model**[12] is a numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and accounting for some of its known properties. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal, and inter-annual climate predictions.

Downscaling[13] is a method that derives local- to regional-scale (10 to 100 km grid) information from larger -scale global models. Steps to translate the global-scale data from GCM (250 - 400km resolution) into the finer resolutions (50 km or less) for use in regional and local impacts analysis are called 'downscaling'. Figure 11 below provides an example of the change in resolution with downscaling for precipitation anomaly pattern.

There are two types of downscaling approaches
- *Statistical downscaling:* Uses the global scale climate as a predictor for producing local scale climate using statistics.
- *Dynamic downscaling:* Use numerical modeling of the dynamics of the physical systems that characterize a region (it works in a similar way to GCMs)

[11] *WGII AR5 Glossary*
[12] *WGII AR5 Glossary*
[13] *ibid*

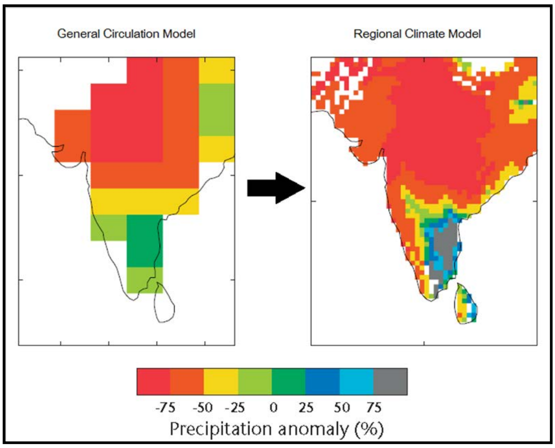

Figure 11: Comparison of Resolution between Global and Regional Model

As the basis for modelling is assumption about the future, there can be uncertainties in the outcomes of modelling. Table 2 below summarizes these uncertainties (confidence levels) based on IPCC documents (TAR, AR4, and SREX). As scientific research provides mare understanding, these uncertainties or confidence levels change. Figure 12 below depicts the process of climate modelling graphically.

Changes in Phenomenon	Uncertainty in observed changes (since about the mid-20th century)			Uncertainty in projected changes (up to 2100)		
IPCC Assessment Report	TAR	AR4	SREX	TAR	AR4	SREX
Higher maximum temperatures and more hot days	*Likely* over nearly all land areas	*Very Likely* over most land areas	*Very Likely* at a global scale	*Very Likely* over nearly all land areas	*Virtually Certain* over most land areas	*Virtually Certain* at a global scale
Higher minimum temperatures, fewer cold days	*Very Likely* over nearly all land areas	*Very Likely* over most land areas	*Very Likely* at a global scale	*Very Likely* over nearly all land areas	*Virtually Certain* over most land areas	*Virtually Certain* at a global scale
Warm spells/heat waves. frequency, length or intensity increases	-	*Likely* over most land areas	*Medium Confidence* in many regions	-	*Very Likely* over most land areas	*Very Likely* over most land areas
Precipitation extremes	*Likely*[1], over many Northern Hemisphere mid- to high latitude land areas	*Likely*[2] over most areas	*Likely*[3]	*Very Likely*[1] over many areas	*Very Likely*[2]	*Likely*[2,4] in many land areas of the globe
Droughts or dryness	*Likely*[5], in a few areas	*Likely*[6], in many regions since 1970s	*Medium Confidence* in more intense and longer droughts in some regions, but some opposite trend exists	*Likely*[5], over most mid-latitude continental interiors (Lack of consistent projections in other areas)	*Likely*[6]	*Medium Confidence*[7] that droughts will intensify in some seasons and areas; Overall *low confidence* elsewhere
Changes in tropical cyclone activity (i.e. intensity, frequency, duration)	Not Observed[8], in the few analyses available	*Likely*[9], in some regions since 1970	*Low confidence*[10]	*Likely*[8], over some areas	*Likely*[9]	*Likely*[11]
Increase in extreme sea level (excludes tsunamis)	-	*Likely*	*Likely*[12]	-	*Likely*	*Very Likely*[13]

Table 2: Confidence Levels of Climate Change Predictions

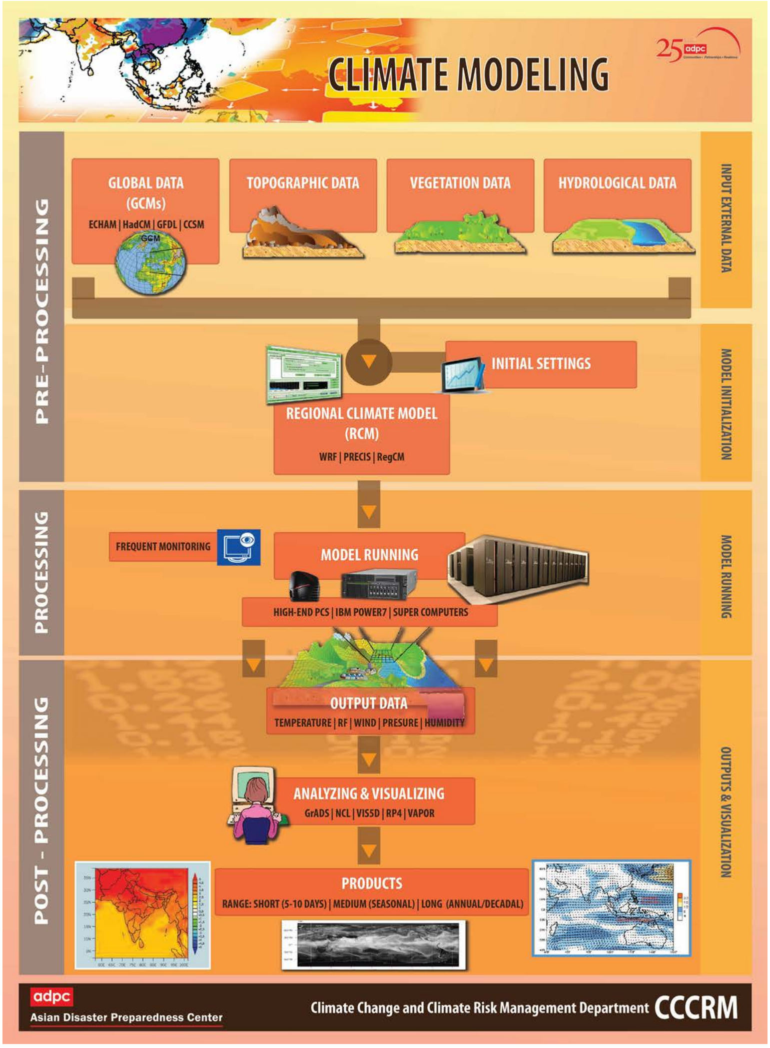

Figure 12: Process of Climate Modelling

A **Climate Prediction**[14] or climate forecast is the result of an attempt to produce (starting from a particular state of the climate system) an estimate of the actual evolution of the climate in the future, for example, at seasonal, inter-annual, or decadal time scales (See Figure 13 below). Since the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.

A **Climate Scenario**[15]: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate.

[14, 15, 16] *ibid*

A **Climate Projection**[16] is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative-forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

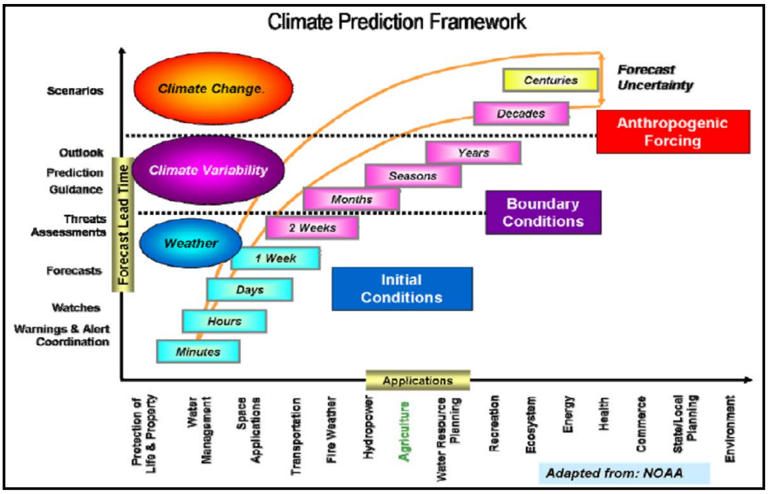

Figure 13: Climate Prediction Framework

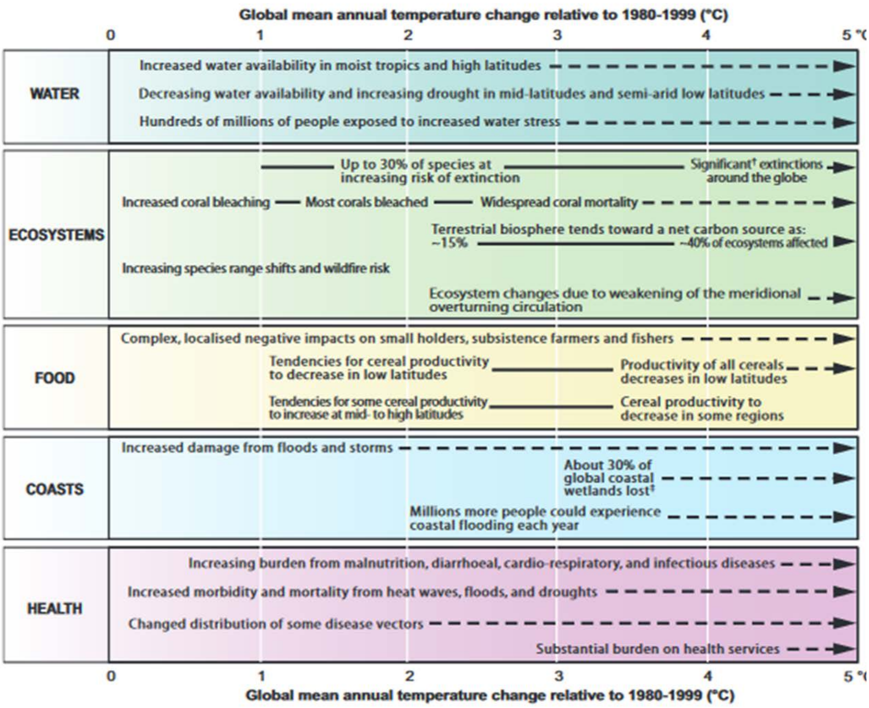

Table 3: Predicted Impacts of Positive Temperature Anomalies up to 50C of the Mean Annual Global Temperature (Source: IPCC)

5. Predicted Impacts on Agro-ecosystems

The two most important factors affecting crop species in relation to climate change is increased CO_2 concentration and temperature. However, the changing of the normal ranges of climate variability influencing changes in precipitation levels and mid-season dry spells as well as the increasing frequency and exacerbated impact of extreme weather events must also be factored in when considering these impacts. Intrusion of salinity is another factor that may negatively impact agro-ecosystems in coastal areas. Lack of tolerance of current crop and livestock varieties to these changes are predicted to decrease agricultural yields and increase the threat of food security. Predicted increases in pest populations and alien species may also contribute to reduction in yields. This may necessitate increased pesticide use which may in turn affect product price levels. The levels of impacts will depend on the exposure levels, sensitivity of crops, livestock and fishery as well as coping capacity of agro-ecosystems.

Crops: Plants are categorized as C3 plants and C4 plants depending on their mechanism of photosynthesis. The majority of the plants are of the C3 type. Example of economically important C4 plants are grasses for fodder, sugar cane, corn, sorghum and millet. Both plant types have been shown to increase biomass production under increased CO_2 concentration and temperature. C4 species are thought to be more competitive under drought conditions[17,18]. However increasing of temperature anomalies above 2^0C may result in sterility of pollen in tropical crops such as rice. Temperate crop varieties might benefit by such temperature change increasing yield initially but may be affected by higher temperature anomalies. Influence of changing climate in reducing insect species may also result in variation of pollination and seed production in many crop varieties.

Livestock: Thornton et al. (2015)[19] suggest that for each 1^0C rise of the mean global annual temperature, most livestock species, such as cattle, sheep, goats, pig and chickens, may reduce their feed intake by 3-5 percent affecting productivity.

Fishery: Marine fish harvest maybe affected by rise in sea temperature and acidification of ocean. Predicted impacts of coral bleaching and their death will decrease primary food productive ecosystems in the ocean which give rise to food chains. Laboratory research by Temasek Life Science Laboratory and Institute of Marine Sciences in Barcelona reinforces earlier findings that rising temperatures may change the sex ratio of fish towards more males[20]. This may have serious repercussion on fish harvest. Brackish water and fresh water aqua culture are also predicted to be affected by climate change.

[17]Ward, J.K., Tissue, D.T., Thomas, R.B. and Strain, B.R. 1999. Comparative responses of model C3 and C4 plants to drought in low and elevated CO2. Global Change Biology 5: 857-867.

[18]Wand, S.J.E., Midgley, G.F., Jones, M.H. and Curtis, P.S. 1999. Responses of wild C4 and C3 grass (Poaceae) species to elevated atmospheric CO2 concentration: a meta-analytic test of current theories and perceptions. Global Change Biology 5: 723-741.

[19]Thornton PK, Boone RB, Ramirez-Villegas J. 2015. Climate change impacts on livestock (PDF). CCAFS Working Paper No. 120

[20]Straight Times, Saturday January 28, 2017, Page B4

Positive impacts of Climate Change

- Lessening of winter temperature may benefit the poor in reducing winter deaths and lessening fuel costs for heating.
- Increasing CO_2 concentrations and temperature below 2^0 Centigrade may positively influence agricultural yields in the temperate countries. According to plant physiology, a stress to plants can increase productivity upto a threshold value.
- This may open up land previously too cold for agriculture.
- In the northern hemisphere, expansion of commercial fishing and shipping passage is expected.

However beyond a threshold value of about 3^0 Centigrade these positive effects may be outweighed by the negative.

6. Global Initiatives to Combat Climate Change

The First Global Response to Climate Change: The first global response to climate change started in the in 1980s, as scientist started to recognize the scale of the climate change problem. By 1988, the general assembly of the United Nations endorsed the creation of an intergovernmental panel on climate change (IPCC), to assess the development of scientific knowledge on climate and climate change to inform decision-making.

IPCC: The IPCC has so far produced 5 Assessment Reports that condense current knowledge on climate change.

UNFCCC: In 1992, the United Nations launched its Framework Convention on Climate Change (UNFCCC) with the objective of stabilizing greenhouse gas concentration in the atmosphere at a level that would prevent dangerous interference with the climate system.

Kyoto Protocol: In 1997, UNFCCC succeeded in creating binding CO_2 reduction target agreement with the Kyoto Protocol, where annex-1 countries committed a collective reduction of 5.2% of their 1990 emissions by 2012. The Kyoto Protocol also included flexibility mechanisms like the Clean Development Mechanism, which was intended as a channel for investment in emission-reduction activities, like clean energy, in non-annex 1 countries, which would also contribute to development and technology transfer.

Conference of Parties (COP) and its milestones: The 197 countries (Parties) who are signatories to the convention, meet every year at a Conference of Parties (COP).

Parties of the UNFCCC are divided between annex 1 and non-annex 1 countries. Annex 1 countries are higher income countries (members of the Organization for

Economic Cooperation and Development) and economies in transition (former Soviet republics). Non-annex parties group the rest of middle and lower income countries. Apart from European Union countries led by Germany, did achieve emission reductions, but the Protocol failed to reach its objective. United States, refused to ratify and comply with the reduction targets and Canada withdrew. Increased emissions by emerging economies like China, India and Brazil, led to a resistance to comply by developed countries.

- *Conference in Bali (2007)* agreed to enhance mitigation (reduction of emissions) and adaptation.
- *Conference in Copenhagen (2009)* abandoned the 1990 level target and set voluntary reduction targets to keep mean temperature rise below 2°C.
- *Cancun (2010)* agreed to discuss an extension of the protocol up to 2020 and initiate a Green Fund to help developing countries.
- *Durban (2011)* reconsidered previous decisions on financing, technology inputs and agreed on Reduce Emissions from Deforestation and Forest Degradation and conservation (REDD+).
- *Doha (2012)* brought the agreement to extend the protocol up to 2020 and to consider 'loss and compensation' to less developed countries.
- *At the Paris Accord (2015),* agreement was reached to hold the temperature increase well below 2°C above pre-industrial levels and increase efforts to limit rise in temperatures to 1.5°C by means of nationally determined reduction of emissions which must achieve a balance between emission sources and natural sinks by mid-century. It will come into effect in 2020 when the Kyoto Protocol ends.

The Paris Agreement also includes a commitment to increase the ability to adapt of developing parties through financial flows which will contribute to craft "low-carbon" development pathways and adaptation.

A number of financial mechanisms and funds have been set up since 1992, including the Special Climate Change Fund (SCCF), the Least Developed Countries Fund (LDCF) and the Adaptation Fund. The SCCF and LDCF have been administered by the Global Environmental Facility (GEF), the financial mechanism of the three Rio Conventions, which included the UNFCCC. At the 2010 16th COP in Cancun, parties agreed on the creation of a new Green Climate Fund, expected to deliver additional funding for adaptation needs amounting to USD 100 billion annually by 2020, which should supply the USD 5 to 7 trillion that is estimated to be needed to achieve the targets of the Paris Agreement. By October 2016, the Green Climate Fund had approved programs on livelihood adaptation, reforestation and clean energy, amounting to a total of USD 2.6 billion.

To reach the ambitious goals of the Paris Accord, several initiatives need to be established. These are:

- appropriate financial flows,
- a new technology framework and
- an enhanced capacity building framework

These measures are expected to support action by developing and most vulnerable countries according to their national objectives.

The Paris Agreement requires all Parties that ratified the accord, to sustain them in the years ahead. All Parties are expected to report regularly on their emissions and on their implementation efforts.

Loss and Damage: UNFCCC defines loss and damage as "the actual and/or potential manifestation of impacts associated with climate change in developing countries that negatively affect human and natural systems," including impacts from extreme events (for example heatwaves, flooding, and drought) and slow-onset events (for example, sea-level rise and glacial retreat).

"Loss" applies to the complete disappearance of something such as human lives, habitats, or even species. These are gone forever and cannot be brought back. "Damage" refers to something that can be repaired, such as a road or building or embankment. Thus loss and damage from climate change refers to the complete and irrecoverable loss of some things and the repairable damage of other things due to the impacts of human-induced climate change (In Disaster Risk Management Loss and Damage refers to things that can be repaired and replaced.) Paris Agreement included anticipatory compensation mechanisms through risk insurance; assured the continuation of the global mechanism on loss and damage - the Warsaw International Mechanism (formulated at COP19, November 2013) and gave recognition to the long-articulated position of many countries that have been arguing for support of short-term coping and longer-term adaptation when mitigation and adaptation efforts are insufficient to deal with the effects of climate change.

Session 1.3.
Agro-ecosystem as a Social Ecological System (SES), and its Resilience and Sustainability

Learning Objectives

At the end of this session, the participant would be able to:

- Explain the concepts of ecosystem and social ecological system
- Describe Resilience of natural ecosystems
- Discuss the need for human interventions to sustain resilience of social ecological systems
- Describe agro-ecosystems as social ecological systems
- Describe the Sustainable Livelihood Approach for rural SES resilience

1. Introduction to the Concept of an Ecosystem

There are living and non-living components in a natural ecosystem that needs to be considered in understanding an ecosystem.

- Defined geographical boundary for study purposes, physical space, air, water, or soil or both, penetration of sunlight
- Presence of plants
- Presence of animals
- Processes of living by both plants and animals, its inputs and outputs
- Processes for by products of plants and animals after death and the process of decaying.

A natural ecosystem is an ecosystem without the influence of human beings to disturb its processes and components.

The term "ecosystem" refers to all of the visible plants and animals, as well as microscopic organisms such as fungi, protozoans, bacteria and other organisms that live in the same area. All of these distinct species share highly interconnected lives and, in many ways, function as one unit. The types of plants and animals are determined by the non-living components of rain fall, temperature, air and soil types and their nutrients etc. which vary from place to place on earth.

Except the incoming energy from the sun and outgoing light and heat, all processes in an undisturbed ecosystem are cyclic processes for Oxygen, Carbon Dioxide, water and nutrients. (See Figure 1). The Water cycle and Carbon cycle were discussed in Session 1.2.

A healthy ecosystem is said to be in *equilibrium*, which is a relatively stable for a particular locality, a state that keeps population sizes within a sustainable range. Natural ecosystems are sensitive to change, such as fire, deforestation, the introduction or removal of species.

The plants are called **Primary Producers**. They absorb energy from the sun and produce carbohydrates from Carbon Dioxide and Water with the release of Oxygen. They oxidize these carbohydrates by absorbing Oxygen to release energy to build living matter nutrients and water absorbed from the soil. This is the process of respiration that is necessary for life. Primary producers are eaten by **Herbivores**. In turn the **Carnivores** predate on herbivores. When plants and animals die the **Decomposers** (microscopic fungi and bacteria) decompose the dead matter and the nutrients are released back to the soil. The interlinking between a primary producer herbivore carnivore decomposer is called a **food chain** (See Figure 2). In reality there are hundreds of such chains in an ecosystem forming a web of food chains. They are self-regulatory systems due to these interlinks.

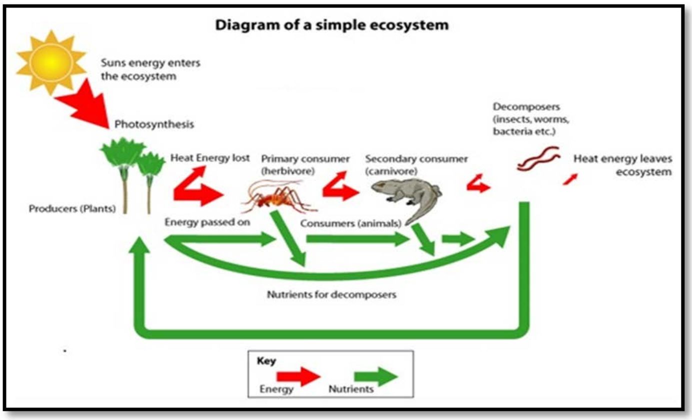

Figure 1: Cyclic processes of an ecosystem (http://www.sciencelearn.org.nz/Contexts/Icy-Ecosystems/Sci-Media/Images/Simple-ecosystem-diagram)

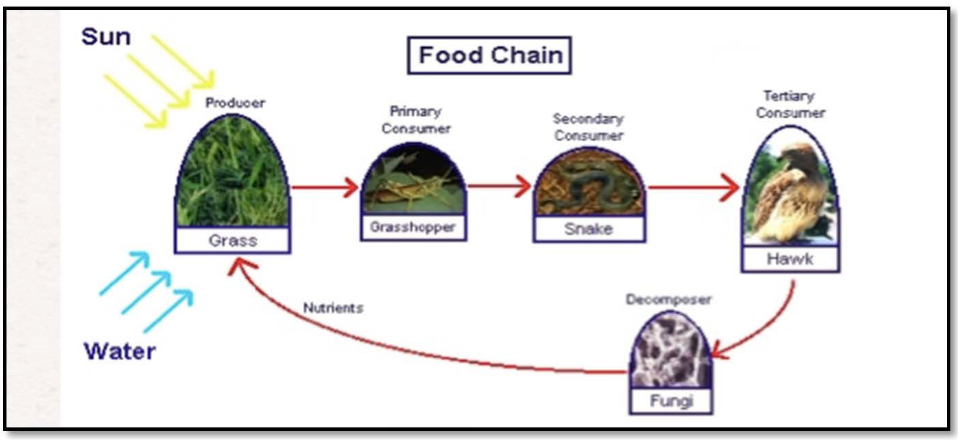

Figure 2: A simple food chain (http://mpalalive.org/classroom/lesson/food-chains-kenya retrieved 11 February 2017)

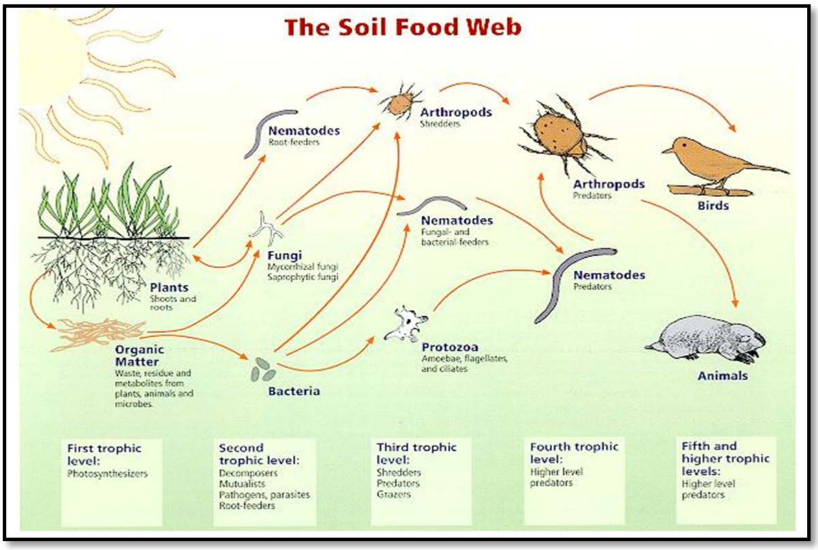

Figure 3: Example of a Food Web (http://oook.info/rbn/Symbiosis/)

2. Resilience and Natural Ecosystems

The word resilience is derived from the Latin word *resilio* which means *"to bounce back",* or to recover quickly from a setback.

The concept was originally applied to ecosystems in equilibrium. If a shock such as a fire or natural disaster impacts an ecosystem in equilibrium such as a rain forest, it may be destroyed. See Figure 4 below.

But if the impacted area is left undisturbed over a long period of time, it will recover into its original state in a sequential process of development called a succession (see Figure below). It happens without human inputs. This ability to bounce back on its own was called resilience. If the forest is only partially destroyed, the recovery time may be faster. The final stage is the equilibrium state possible within the climatic and physical conditions of the area and is called a climax. It thereafter remains unchanged if no external shocks impact it.

Holling (1996)[4] distinguished two aspects of resilience.

- One is the **time to recovery**, the rate and speed of return to pre-existing conditions after a disturbance.
- The other is the magnitude of **disturbance that can be absorbed** before the system changes its structure by changing the variables and processes that control behavior.

One aspect of resilience is therefore a resistance to change. The other is to bounce back after a disturbance. Figure 5 illustrates these two faces of resilience.

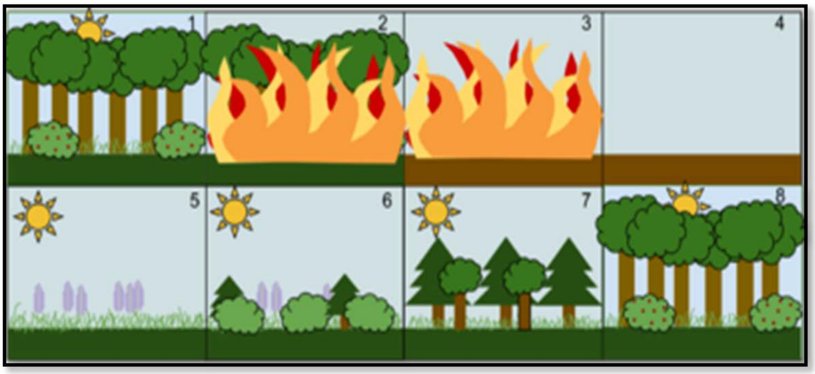

Figure 4: Bouncing back process of a destroyed forest.

Current use of the Term Resilience

The term resilience is now being applied to individuals, household, communities, institutions, infrastructure, critical facilities and social networks etc. Different disciplines of study connote different perceptions and therefore the term must be interpreted in the context of each discipline.

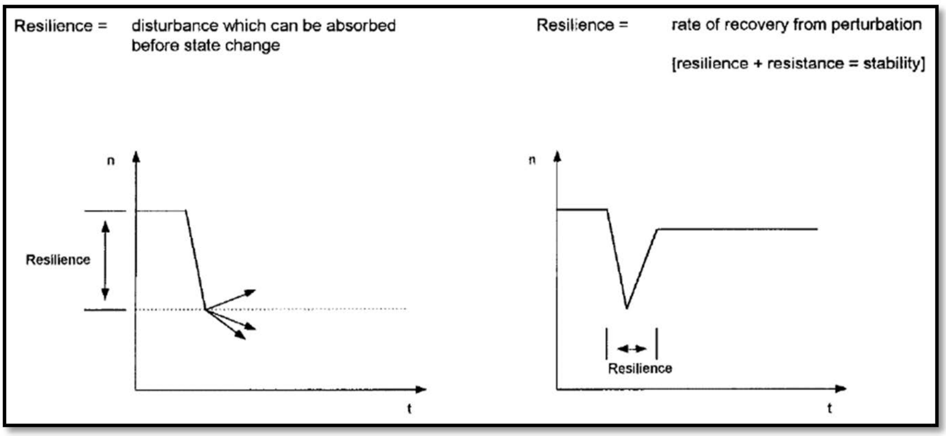

Figure 5: Two faces of resilience (After Adger 2000)[5]. Two faces of resilience appear to be the disturbance which can be absorbed before the dynamic equilibrium is changed completely (left) and the rate of recovery from a disturbance (right).

3. Concept of a Social-Ecological System Ecosystem

A social system or human settlement (community) has to depend on an ecological system for many requirements (called ecosystem services) and therefore the two are thought of as linked into one system (See Figure 5 below). The sustainability of both are interlinked and need constant monitoring and human inputs. Over exploiting an ecosystem can lead to its degradation and therefore monitoring and conservation measures are essential for sustainability.

Berkes et al. (2001)[6] used the concept of social ecological systems to emphasize the integrated concept of humans in nature and to stress that the delineation between social systems and ecological systems is artificial and arbitrary. Figure 6 attempts to depict this interlink.

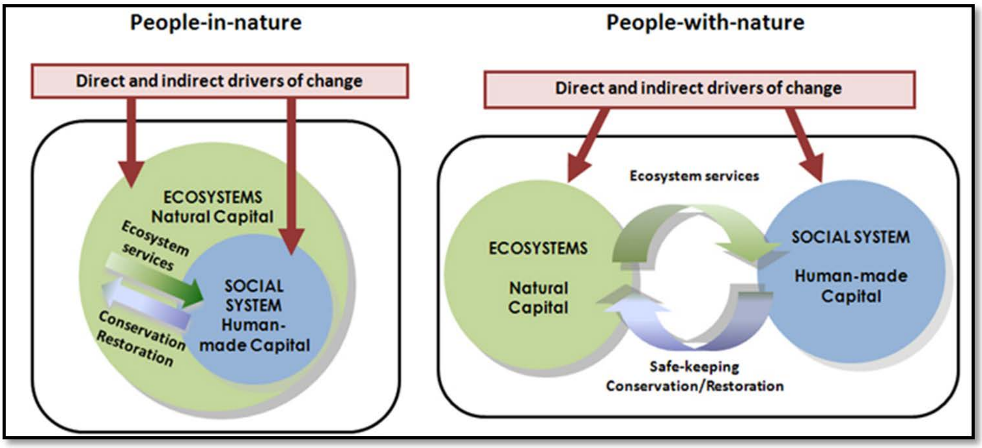

Figure 6: Social Ecological Systems (http://www.ecologyandsociety.org/vol13/iss2/art13/figure6.html)

The Millennium Ecosystem Assessment's diagram below provides further detail on the links between ecosystem services and human well-being. According to Cumming (2005)[7] components of a socio-ecological system can be thought of as the pieces of the system that interact in a dynamic way. These components include:

- human actors of various kinds,
- particular ecosystem types or habitat types,
- level of exploitation of resources, goods and materials,
- abiotic (nonliving) variables.

System components interact or fit together. Examples of relationships are nutrient cycles, food webs, economic and ecological competition, land tenure, and interactions between human actors through social networks. Biological diversity is of paramount importance to the sustainability of a Social ecological system and its continued supply of ecosystem services. The ecosystem services that an ecosystem provides for a human settlement are depicted in Figure 7.

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[6]*Berkes, F., Colding, J., and Folke, C. (2001) Linking Social-Ecological Systems. Cambridge: Cambridge University Press*

[7]*Cumming, G.S., Barnes, G., Perz, S., Schmink, M., Sieving, K.E., Southworth, J., Binford, M., Holt, R.D., Stickler, C. and Van Holt, T., 2005. An exploratory framework for the empirical measurement of resilience. Ecosystems, 8: 975-987.*

[8]*USGCRP (2009). Global Climate Change Impacts in the United States. "Climate Change Impacts by Sectors: Ecosystems." Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). United States Global Change Research Program. Cambridge University Press, New York, NY, USA.*

Ecosystems form natural buffers to wildfires, flooding, and drought. Climate change and human activity may reduce ecosystems' ability to serve as buffers. Examples include reefs and barrier islands that offer protection from coastal storm surges, wetland ecosystems that serve as floodwater retention areas, and small cyclical wildfires in limited areas that clear forest debris and act as fire reducing belts[8].

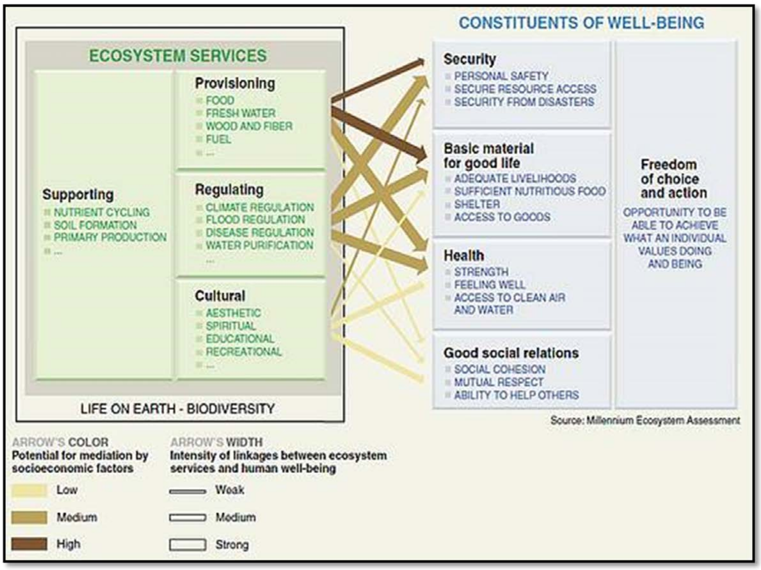


Figure 7: Ecosystem Services[10]

4. Resilience of a Social Ecological System

Timmerman (1981)[11] is probably the first to use the concept of resilience in relation to hazard and disaster in a social ecological system (or a human settlement) and defined the term "resilience" as the measure of a system's or part of the system's capacity to absorb and recover from hazardous event or shock.

However, a social ecological system cannot bounce back on its own like a natural ecosystem. **It needs a tremendous amount of human interventions** (unlike the bouncing back of a natural ecosystem in equilibrium) to come back to the original state and the time taken will depend on the resources available.

The level of resilience in the social ecological system e.g. a community at risk, will determine the extent of bouncing back and the time taken to do it. Current disaster recovery paradigm to "build back better" expects that the community will bounce back to a higher level than before. This is depicted in Figure 8 below.

[10]http://www.millenniumassessment.org/en/Synthesis.aspx retrieved 11 February 2017.
[11]Timmerman, P. 1981. Vulnerability, resilience and the collapse of society. Environmental Monograph 1, Institute for Environmental Studies, University of Toronto, Toronto, Ontario, Canada.

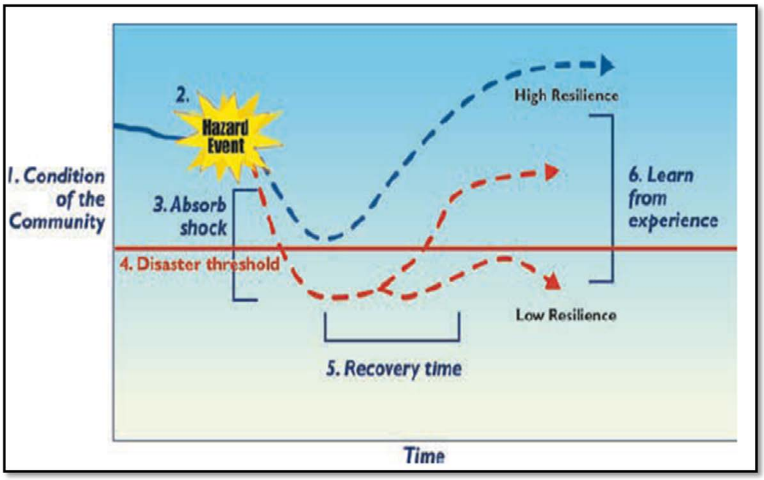


Figure 8: Bouncing back level based on the level of community resilience. The blue line represents building back better after a disaster.

According to Resilience Alliance[12], resilience is the ability of an interdependent social ecological system to absorb disturbances and maintain the same structure and function. Resilience maybe thought of as the "flip side" of vulnerability. Decreasing vulnerability increases resilience. According to IUCN[13], ecosystem-based disaster risk reduction refers to decision-making activities that take into consideration current and future human livelihood needs and bio-physical requirements of ecosystems. This is recognition of the role of ecosystems in supporting communities to prepare for, cope with and recover from disaster situation.

Level of resilience will determine the ability to bounce back or collapse as shown in Figure 9[14].

If a SES is pushed into an undesirable context and cannot be returned to its former state, the capacity to create a fundamentally new system with new variables, new livelihoods, and different scales of organization may be possible through its transformative ability (See Figure 10).

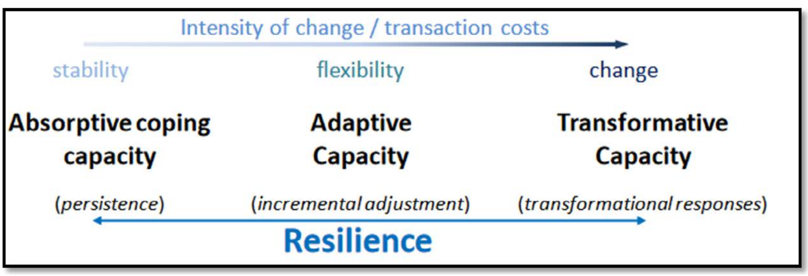


Figure 10 Resilience Framework of an SES[15]

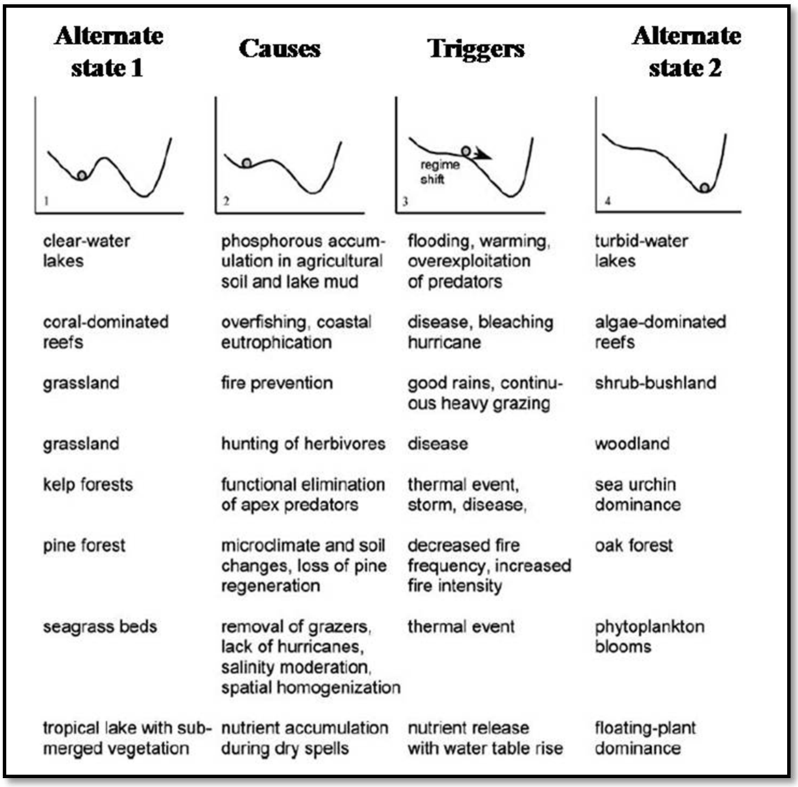


Figure 9: Shift of Social Ecological System to an Alternate State

According to Béné et.al (2012), *"the salient point of the framework (Fig. 10) is the fact that resilience emerges as the result not of one but all of these three capacities: absorptive, adaptive and transformative capacities, each of them leading to different outcomes: persistence, incremental adjustment, or transformational responses. Figure also suggests that these different responses can be linked (at least conceptually) to various intensities of shock or change. The lower the intensity of the initial shock, the more likely the household (or individual, or community, or system) will be able to resist it effectively, i.e. to absorb its impacts without consequences for its function, status, or state."*

[12] *http://www.resalliance.org*

[13] *http://www.iucn.org/about/work/programmes/ecosystem_management/disaster/about_drr/*

[14] *http://www.openlandscapes.zalf.de retrieved 12th February 2017.*

[15] *Béné, C.; Wood, R.G.; Newsham, A.; Davies, M.Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programs; Wiley: New York, NY, USA, 2012.*

5. Ecosystem Degradation and its Negative Impacts on Communities

The UN ISDR) Global Assessment Report (GAR 2009) identified ecosystem degradation as one of the main drivers of disaster risk worldwide. Environmental degradation reduces the capacity of ecosystems to meet people's need for food and other products, and to protect them from hazards through services such as flood regulation, slope stabilization, and protection from storm surges. Additionally, ecosystem degradation reduces the ability of natural systems to sequester carbon that increases the incidence and impact of climate change and climate change related disasters.

According to Adger (2000)[16], rural social ecological resilience refers to the capacity of a rural region to adapt to changing external circumstances in such a way that a satisfactory standard of living is maintained while coping with its inherent ecological, economic and social vulnerability. Rural resilience describes how rural areas are affected by external shocks and how it influences system dynamics.

Rural areas are undergoing major changes, driven by ecological, spatial and sectoral forces. Such changes have large environmental impact in terms of land use, landscape changes, environmental pollution and biodiversity loss, and large economic impact in terms of changing demographics through migration, reduction in agricultural employment and diversification of the rural economy[17]. These changes may be exacerbated by climate change with negative impacts on their resilience.

6. Agro-Ecosystems as Social Ecological Systems

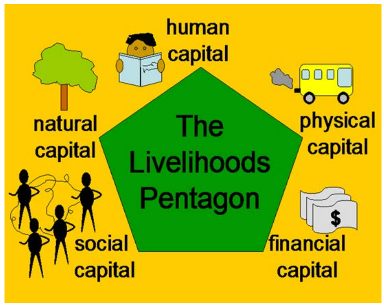
Agricultural systems whether they are farmlands, livestock, aquaculture, brackish fish culture, agro fuels or economic crops are associated with human settlements and are social ecological systems. Their size may differ due to industrialized or mechanized farming. However, they are mostly rural and located away from urban centers. If they are irrigated for example, then they in turn depend on natural ecosystems for their services.

They lack the biological diversity of natural ecosystems and tend to be monocultures. These are very vulnerable to pests, diseases and increased climate variability that maybe induced by climate change. They are economically advantageous but are not self –regulatory like natural ecosystems and need intense human inputs to keep them at a sustainable level. With disaster impacts or other shocks, they have very low resilience and need special protective measures to increase their coping abilities. Many crops, livestock and fish varieties show sensitivities to climate change and needs special adaptation measures to build resilience.

7. Sustainable livelihoods for Rural SES Resilience

Ecosystems and the services they provide have more importance for livelihoods of rural communities. These livelihoods are said to be influenced by five types of assets (or capital domains) as shown in Figure 11. Ecosystem services fall under the natural assets[18].

Human capital (H) skills, knowledge, good health and ability to work.
Social capital (S) formal and informal social relationships, including how much people trust each other, how reliable and adaptable they are.
Natural capital (N) natural resources such as soil, crops and trees, and the ecosystem services that nature brings
Physical capital (P) goods and physical things that have been made, such as fences, houses and roads
Financial capital (F) money and access to credit and loans



Source: blogs.ubc.ca

Figure 11: Livelihood Assets of Rural Communities

People in rural communities have different uses and needs for ecosystem resources such as forests, water, pastures and land, etc. Knowing about these different needs and interests can help to inform successful ecosystem based management to benefit all stakeholders.

Factors that influence livelihood strategies

Natural resources are increasingly subject to intense competition due to:

- Demographic change (e.g. population growth, migration and urbanization)
- Market pressures (e.g. increased commercialization, intensification and privatization of local economies, growing integration of national and global economies, economic reforms)
- Environmental changes that force people to alter their livelihood strategies (e.g. floods, recurrent droughts, altered river flows, changes in wildlife migration and climate change impacts).

These forces can lead to excessive harvesting renewable natural resources (forests, water bodies, grazing areas, marine resources, wildlife and agricultural land etc.) reducing their sustainability. In areas where the number of people is increasing, resources have to be shared among more users with different interests. Examples range from farmers seeking access to agricultural land to cater to increasing demand from urban centers, and pastoralists requiring pasture resources for livestock.
Scarcity of resources can also bring about conflict.

[16]*Adger, Neil. W., (2000). Social and ecological resilience: are they related?, Progress in Human Geography 24,3 pp. 347–364*
[17]*Schouten, Marleen. van der Heide, Martijn., and Heijman, Wim., (2009).Resilience of social-ecological systems in European areas : Theory and Prospects,113th EAAE Seminar, Belgrade*
[18]*http://www.fao.org/docrep/008/a0032e/a0032e04.htm*

The strategies that households develop to ensure their livelihoods depend on:

- how they can combine their livelihood assets and the level of access to them
- how vulnerable they are where they live to natural disasters and climate change
- The policies, institutions and processes that affect them.

Figure 12 below depicts these relationships.

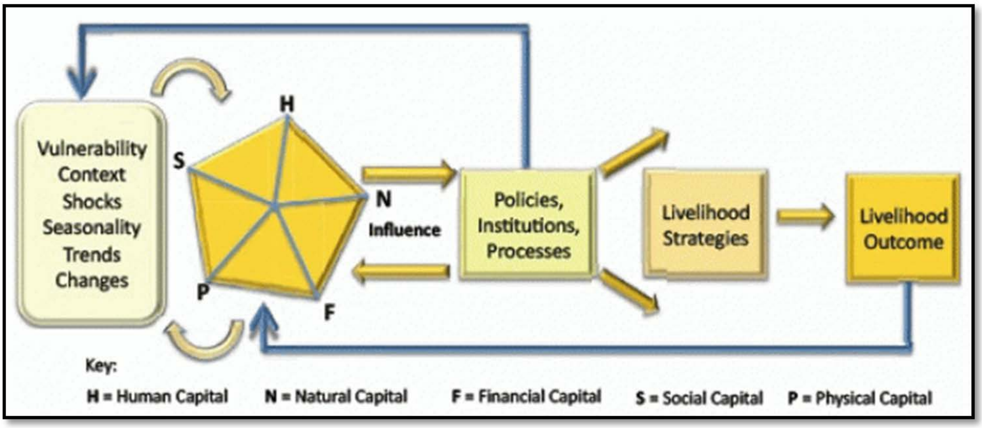


Figure 12: Factors that influence Livelihood strategies and outcomes
(Source: www.methodfinder.net)

In any society, assets are distributed unevenly. Gender, age and other differences affect equity of access to assets. People who have many wider choices about how they can make a living (strategies they can use) are usually less vulnerable than those with limited choice. Sustainable livelihood approaches are about addressing these issues. Some of the tools of conflict management, such as consensual negotiations, can help.

Sustainable Livelihood Approach (SLA)

The sustainable livelihoods approach (SLA) idea was first introduced by the Brundtland Commission on Environment and Development as a way of linking socioeconomic and ecological considerations in a cohesive, policy-relevant structure.

Ideally, an effective sustainable livelihoods approach should generate more income, increase well-being, reduce vulnerability, improve food security and result in more sustainable use of natural resources for its beneficiaries as depicted in Figure 13 below.

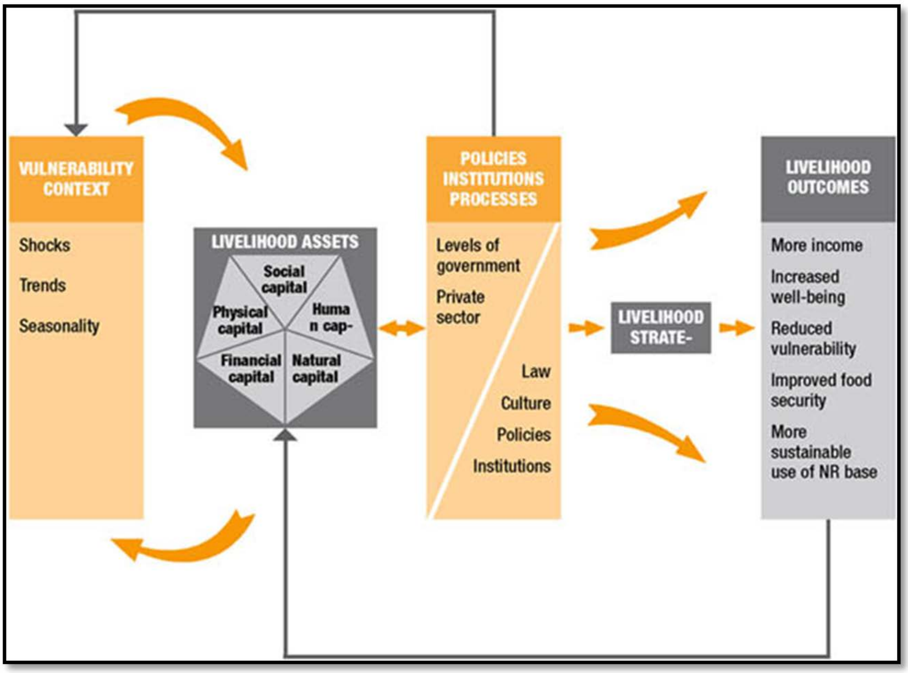


Figure 13: Sustainable Livelihood Approach (Source: www.fao.org)

Session 1.4.
Introduction to Ecosystem based Approaches to Build Resilience of Farmland Agro-ecosystems

Learning Objectives

At the end of this session, the participant would be able to:

- Explain Ecosystem based Approaches
- Describe agro-ecological principles for farming systems on land
- Discuss approaches to enhance agroecological resilience using agroecological principles

1. Introduction to Ecosystem Based Approaches (EbA)

EbA is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change. Eco-system-based Adaptation uses sustainable management, conservation, and restoration of ecosystems to build resilience and decrease the vulnerability of communities in the event of climate change[1]. EbA takes into account the social-ecological system (SES) concept to climate change adaptation.

According to World Bank (2010)[2], climate change adaptation pathways can be of four categories:

- Grey adaptation
  - These are capital-intensive and are engineered constructions.
- Soft adaptation
  - These include changes in policies and behavior of individuals, societies, and institutions, and complements EbA responses.
- Green or Ecosystem-based Adaptation (EbA)
  - These use biodiversity and ecosystem services to formulate an adaptation strategy from a social ecological system perspective.
- Community-based adaptation (CBA) measures

EbA is a recent paradigm but uses strategies that have been applied under ecosystem restoration, soil and water conservation, and disaster risk reduction (Munroe et al. 2011). Depending on the local context and objectives to be achieved, EbA measures may need to be complemented by other options. An array of different options may become necessary to achieve the adaptation required. An example may be efforts to protect coastal SESs from coastal floods with mangrove planting may be successful only if land-use planning as well as early warning capacities are put in place. It is also necessary to understand that EbA options may not necessarily the optimal option in some situations.

Cost effectiveness is usually carried out to choose between alternative options for adaptation. However EbA strategies may pose constraints as valuation of ecosystem services and ensuring their sustainability is still an uncertain area. But as there is uncertainty about climate change predictions and very accurate projections for a particular location may not be possible. Therefore EbA measures can be low-cost options that will not incur heavy loss of investment if predicted impacts do not occur. Where relevant, they are also no-regret measures meaning that they will cause no harm or prospective risk.

According to Locatelli *et.al.* (2008), when ecosystem services are relevant for example fisheries or farming, climate change adaptation should assess vulnerabilities of both ecological and social systems of an SES simultaneously, and consider the links between them[3]. Figure 1 depicts this interlink between the social and ecological components of an SES.

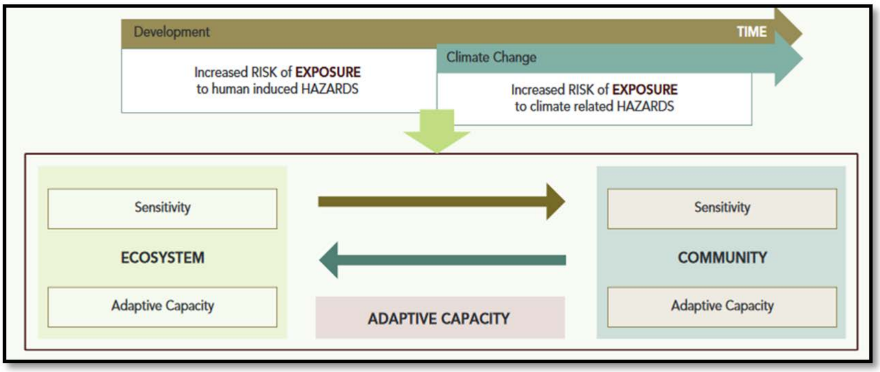


Figure 1: Interlink between social and ecological systems of an SES[4]

The International Assessment in Agricultural knowledge, Science and Technology for Development (IAASTD)[5], states that future of agriculture lies in biodiverse agroecological based farming that can meet social, economic and environmental goals as well as maintain and increase productivity.

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[1]*Convention on Biological Diversity (CBD). 2009. Connecting Biodiversity and climate change Mitigation and adaptation: Report of the Second Ad-Hoc Technical Expert Group on Biodiversity and climate change. Montreal, Technical Series No. 41, http://www.cbd.int/doc/publications/cbd-ts-41-en.pdf*
[2]*World Bank. 2010. Economics of adaptation to climate change: Synthesis Report. The World Bank, Washington D.C. http://siteresources.worldbank.org/EXTCC/Resources/EACC_FinalSynthesisReport0803_2010.pdf.*
[3]*Locatelli, B., Kanninen, M., Brockhaus, M., Colfer, C.J.P., Murdiyarso, D. and Santoso, H. 2008 Facing an uncertain future: How forests and people can adapt to climate change. Forest Perspectives no. 5. CIFOR, Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/media/CIFOR_adaptation.pdf*
[4]*UNFCCC (2011) Ecosystem-based approaches to adaptation: compilation of information. http://unfccc.int/resource/docs/2011/sbsta/eng/inf08.pdf.*
[5]*IAASTD (2009). Agriculture at a Cross Road, Island Press, Washington, DC. http://www.agassessment.org*

Introduction to Agroecology

Agro-ecology is the application of science of ecology to agricultural systems on land and embeds the paradigm of SES. It is a science that attempts to bridge ecological and socio-economic aspects. The concept is graphically illustrated in Figure 2.

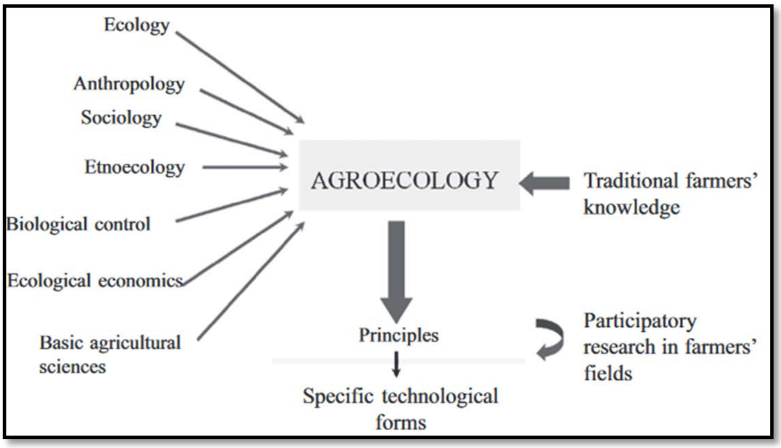

Figure 2: Graphical Depiction of the Concept of Agroecology[6]

The basic premise for agroecosystems is to mimic biodiversity of natural ecosystem as far as possible. This would encourage polyculture, agroforestry and crop-livestock integration. The Box 1 below shows some of the components that could be encouraged.

Agro-ecology principles emphasize soil quality and plant health to enhance beneficial soil microorganisms and nutrients as well as to reduce pest and weed infestations while also enhancing landscape heterogeneity associated with agro-ecosystems that harbor predators of pests in crops. Animals can also help such as fish species in paddy fields feed on weeds, larvae of pests. Their movement can dislodge pests such as locusts from paddy to be eaten by fish. Figure 3 below graphically represents a diversified farming system.

According to Pretty (2003)[8], such diversified farming systems become complex social-ecological systems through development of social institutions, practices, and governance processes that collectively manage food production and biodiversity.

Building Resilience of an Agroecosytem

This section gratefully acknowledges the *Guide to Developing and promoting agroecological innovations within country program strategies to address*

[6]*Adopted from Third World Network and SOCLA (2015).Agroecology: Key Concepts, Principles and Practices, Jutaprint, Malaysia. https://foodfirst.org/agroecology-key-concepts-principles-and-practices/*
[7]*ibid*

[8]*Pretty, J. 2003. Social capital and the collective management of resources. Science 302:1912-1914.*

Crop rotations: Temporal diversity in the form of cereal-legume sequences. Nutrients are conserved and provided from one season to the next, and the life cycles of insect pests, diseases, and weeds are interrupted.

Polycultures: Cropping systems in which two or more crop species are planted within certain spatial proximity, resulting in biological complementarities that improve nutrient use efficiency and pest regulation, thus enhancing crop yield stability.

Agroforestry systems: Trees grown together with annual crops, in addition to modifying the microclimate, maintain and improve soil fertility as some trees contribute to nitrogen fixation and nutrient uptake from deep soil horizons while their litter helps replenish soil nutrients, maintain organic matter, and support complex soil food webs.

Cover crops and mulching: The use of pure or mixed stands of grass-legumes, e.g., under fruit trees, can reduce erosion and provide nutrients to the soil and enhance biological control of pests. Flattening cover crop mixtures on the soil surface in conservation farming is a strategy to reduce soil erosion and lower fluctuations in soil moisture and temperature, improve soil quality and enhance weed suppression, resulting in better crop performance.

Green manures are fast-growing plants sown to cover bare soil. Their foliage smothers weeds and their roots prevent soil erosion. When dug into the ground while still green, they return valuable nutrients to the soil and improve soil structure.

Crop-livestock mixtures: High biomass output and optimal nutrient recycling can be achieved through crop-animal integration. Animal production that integrates fodder shrubs planted at high densities, intercropped with improved, highly-productive pastures and timber trees all combined in a system that can be directly grazed by livestock, enhances total productivity without need of external inputs.

Box 1: Components for Agroecosystems to Enhance Biodiversity[7]

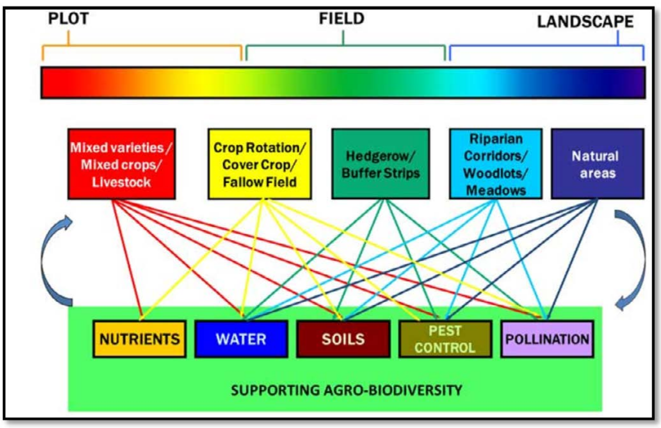

Figure 3: Diversified Farming System[9]

agroecosystem resilience in production landscapes (2016)[10], which is an output under the aegis of the Small Grants Programme (SGP) of the Global Environment Facility (GEF) implemented by the United Nations Development Programme (UNDP).

[9] *Kremen, C., A. Iles, and C. Bacon. 2012. Diversified farming systems: an agroecological, systems-based alternative to modern industrial agriculture. Ecology and Society17 (4): 44.*
[10] *http://agroeco.org/wp-content/uploads/2016/03/GEF-SGP-Guidance-Note.pdf*

The guide aims to facilitate:

- Engagement smallholder organizations
- Enable community participatory analysis of agroecosystem vulnerability to impacts of climate change
- Identification of resilience enhancing innovations
- Identification of resilience outcomes
- Testing and implementation of innovations
- Monitor progress, analyze, and evaluate results.

According to Nicholls and Altieri (2013)[11]

$$\text{Risk} = \frac{\text{Vulnerability} * \text{Threat}}{\text{Response Capacity}}$$

According to them, these terms are defined as follows:

Risk	is understood as any natural phenomena (drought, hurricane, flood, etc.) that signifies a change in the environment inhabited by a rural community.
Vulnerability	is determined by biophysical features of the farm and socio-economic conditions of the farmers that enhance or reduce the exposure to the threat.
Threat	is the climatic event's intensity, frequency, duration, and level of impact (i.e., yield losses due to storm or drought).
Response capacity	is the ability (or lack of) of the farming systems and the farmers to resist and recover from the threat depending on the level of social organization and the agroecological features (i.e., crop diversity) of the farms.

Sociological features that contribute to resilience or lack of it are depicted in Figures 4, 5, 6 & 7 below.

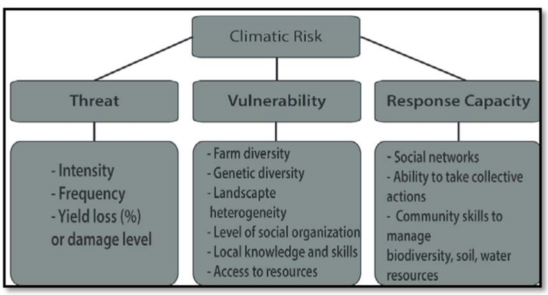

Figure 4: Socioecological features that influence resiliency of farms[12]

[12]*http://agroeco.org/wp-content/uploads/2016/03/GEF-SGP-Guidance-Note.pdf*

Figure 5: Monocultures are more vulnerable to climate stresses (Source: ibid)

Figure 6: Biodiverse systems confer higher production stability (Source: ibid)

Figure 7: Farms in a complex landscape matrix exhibit higher resilience (Source: ibid)

Indicators of Resilience and Sustainability of an Agroecosystem

These indicators should be built around agroecological principles already described earlier. They must be measurable by the farming practitioner without outside technical expertise. Some indicators maybe sub-divided into smaller discrete entities or sub-sets. An example could be as follows.

Indicator 1
- Sub-indicator 1.1. Soil cover
- Sub indicator 1.2. Soil organic matter
- Sub-indicator 1.3. Soil moisture content etc.

Indicators may need to change depending on the local context, but the following example demonstrate the approach towards building agroecological resilience. An indicator can be subjectively assigned a rank of (1 to 5). (1), will be least desirable while (5), indicates the most desirable state.

Once the indicators are chosen and they are assigned the subjective ranking, a spider diagram could be drawn, which can show the building up of the resilience from a benchmark situation.

A hypothetical example is given in Figure 8.

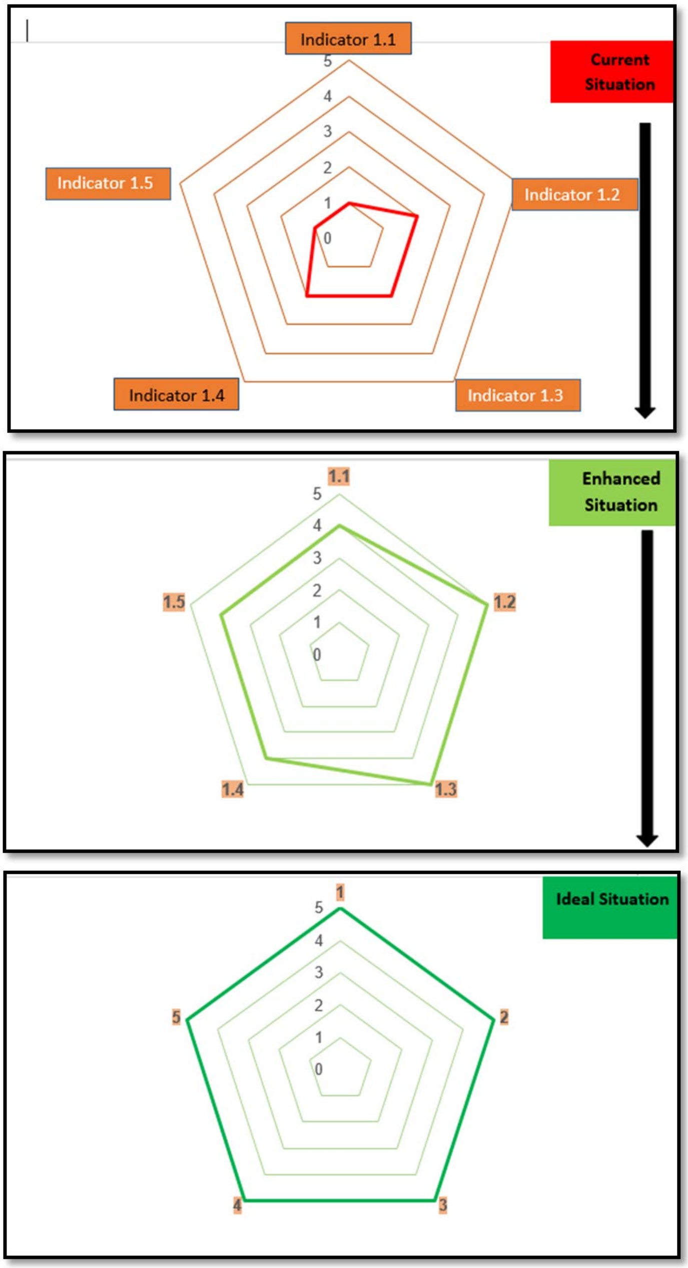

Figure 8: Use of Spider Diagram to Monitor Enhancement of an Indicator sub-sets

The following indicators have been adopted from Third World Network and SOCLA (2015)[13].

Indicator	Example
Landscape diversity	Amount and type of vegetation surrounding the farm
Crop and animal diversity	Number of species
Genetic diversity	Number of local crop varieties and / or animal races
Soil quality	Organic matter content, structure, soil cover, infiltration etc.
Prevention of degradation	Measures to sop Soil erosion, deforestation, increase in efficiency of water use, habitat fragmentation etc.
Plant Health	Reduction of pests, weeds, crop damage
Reduced external inputs	Percentage reduction of external inputs to the farm
Food Self-sufficiency	Percentage of food originating in farm
Bio-resource flows	Recycling of crop residues and manure,
Resilience to external shocks	Capacity to resist and recover from pests, storms, droughts etc.

Table 1: Desirable Indicators for an Agroecosystem Resilience

Figure 9 depicts the improvement of response capacity of an agroecosystem through agroecological practices compared to conventional practices.

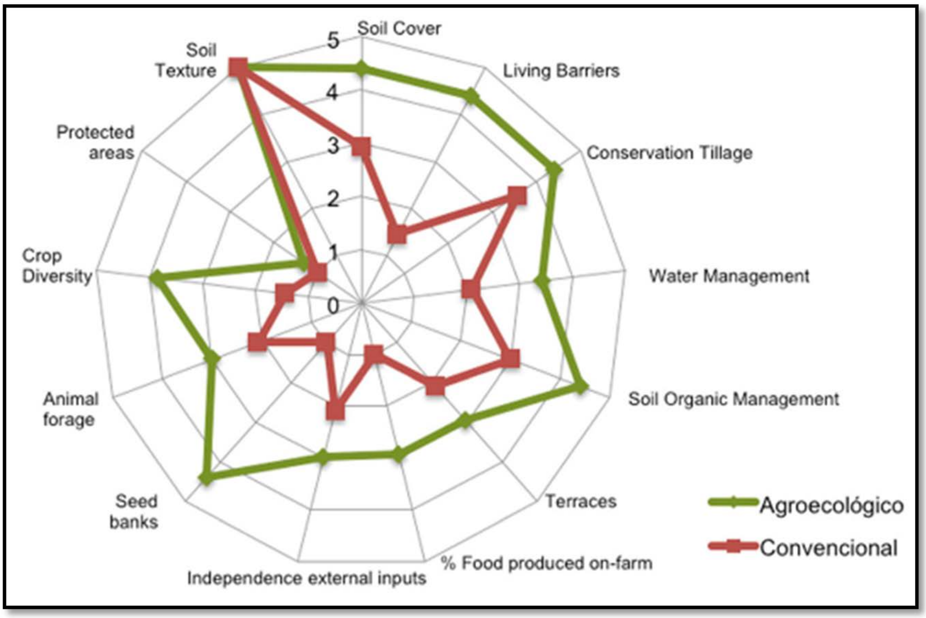

Figure 9: Improvement of Response Capacity through Agroecological Practices[14]

[13]*Third World Network and SOCLA (2015).Agroecology: Key Concepts, Principles and Practices, Jutaprint, Malaysia. https://foodfirst.org/agroecology-key-concepts-principles-and-practices/*
[14]*Henao SJ (2013) Propuesta metodológica de medición de la resiliencia agroecológica en sistemas socio-ecológicos: un estudio de caso en Los Andes Colombianos. Agroecología 8(1):85-91*

Module 2

Generation and Application of Weather and Climate Related Information

Session 2.1.
Weather Forecasting, Climate Information Generation and Their Application

Learning Objectives

At the end of this session, the participant would be able to:
- Explain and differentiate between weather and climate
- Discuss variability of weather patterns and climate
- Explain weather forecasting and its applications focused on agro ecology
- Describe climate outlooks and their applications focused on agro ecology

Weather: The weather at any given place is just the state of the atmosphere at any time (or short period of time), including things such as temperature, precipitation, wind speed and direction, air pressure, cloud cover, etc. Therefore, weather describes the short-term state of the atmosphere in a given location. Daily changes in the weather are due to physical and dynamical processes.

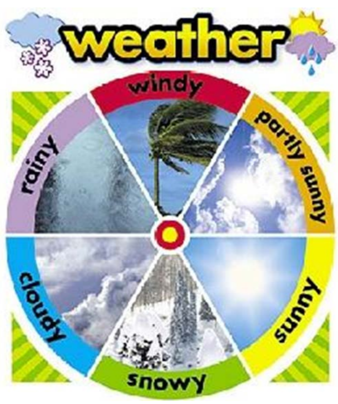

Figure 1: Graphical Representation of different weather patterns

Climate: Climate is the average weather usually taken over a long period of time (typically 30 years) for an area or a region (eg. Tropical, Sub-tropical, Mediterranean, etc.). Climate is not static but is continuously changing due to natural and human induced factors. Fig 2 depicts the annual globally averaged combined land and ocean temperatures from 1850 to 2012, which depicts annual climate variability and climate change in terms of annual average and decadal temperature, respectively.

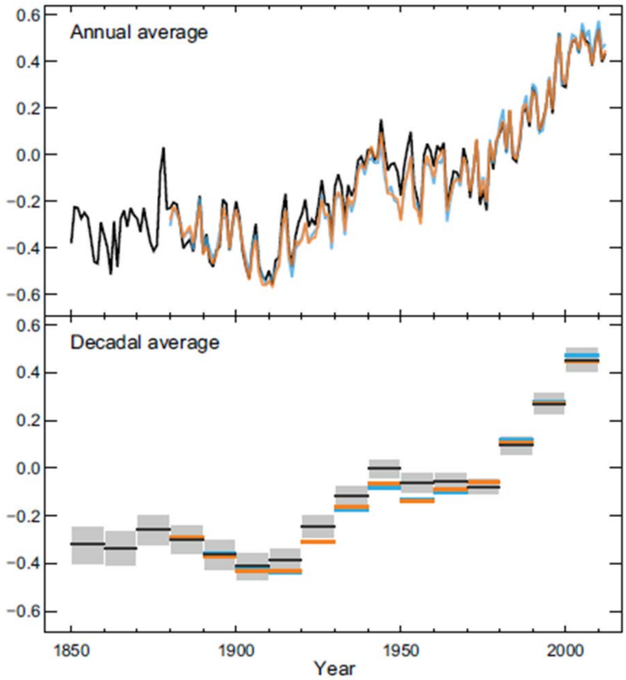

Figure 2: Climate Variability and Climate Change (Source: IPCC 5th Assessment Report)

Seasons: Seasons are annually recurring periods differentiated by weather. Seasonal changes are due to the Earth revolving around the sun. Different areas of the world experience seasons differently. Temperate and Polar Regions which are far from the equator experience spring, summer, autumn and winter (Fig 3). In the tropics, many regions experience wet and dry seasons links to monsoons and wind cycles.

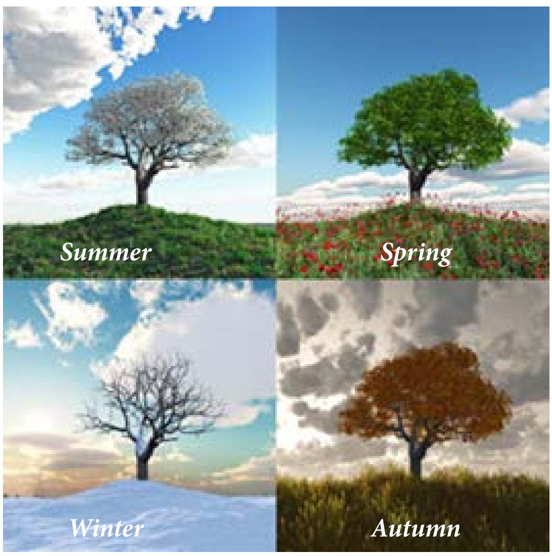

Figure 3: Four seasons

Weather Forecasting: Weather forecasting is a prediction of what the weather likely to be in hourly, daily, or weekly. Weather forecasting involves a combination of knowledge in historical and real time observations with the assistance of computer models. By using these methods, reasonable and accurate forecasts can be made up to a few days in advance.

The below table depicts different types of forecast products

Forecast Product	Lead Time
Short Range	1-3 days
Medium Range	3-10 days
Extended Medium Range (sub-seasonal)	10-25 days
Long or Seasonal	1 month and beyond

Seasonal Scale Climate Forecasts: Most seasonal scale climate forecasts are based on expectations of future state of the atmosphere (temperature and precipitation, etc.) derived from long-term climate trends, the current and anticipated state of sea surface temperatures, expert judgments, and other diagnostic tools. No forecast, however, is perfect. As a result, they are often presented in probabilistic (chance of occurrence) terms. Nowadays many seasonal scale forecasts are available for decision makers, planners, managers, etc.

Climate Outlook: Climate outlook is only a prediction, or best estimate, of future climate, using what we know to be the most likely conditions from climate science and from past records. Climate Outlook gives probabilities that depicts below-normal, normal, or above-normal conditions averaged over a specified period. It provides a tool for decision makers to understand anticipation of poor, fair or good seasons. The aim of climate outlooks is to better equip investigators to respond to longer-term climate variability and change in a sustainable manner.

A user-friendly, climate outlook could provide valuable basis for:

- Raising public awareness and support for action on climate change and vulnerability reduction programs
- Planning for national, regional or sectoral climate resilient development
- Investment in and the development of appropriate infrastructure and climate sensitive planning
- Avoidance of high-risk areas through land use regulations
- Incorporation of climate change allowances in the engineering standards applied to flood defenses and water supply systems
- The management of natural resources
- Adaptation options for economic growth strategies

Accessing climate outlooks: Climate outlooks can be accessed from:

- National Meteorological Offices
- National Ministries of Environment
- International Research Institute for Climate and Society (IRI): *http://iri.columbia.edu/our-expertise/climate/forecasts/#Seasonal_Climate_Forecasts*
- APEC Climate Center: *www.apcc21.org*
- European Centre for Medium-Range Weather Forecasts (ECMWF): *www.ecmwf.int/*
- National Centre for Medium Range Weather Forecasting (NCMRWF): *http://www.ncmrwf.gov.in/*

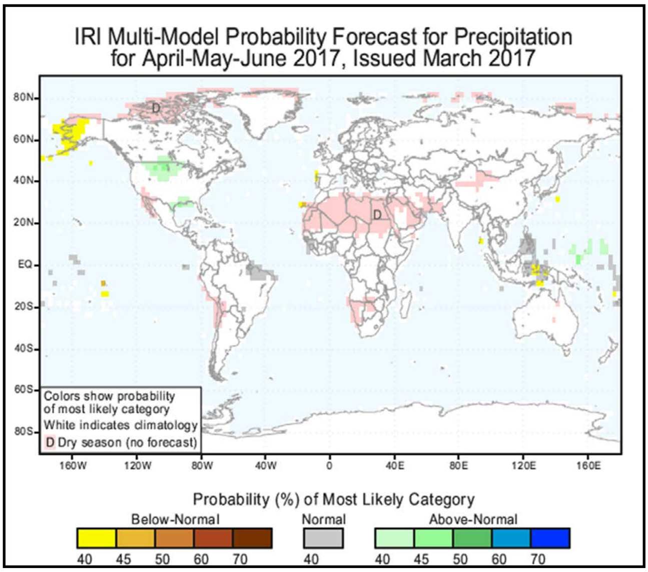

Figure 4: A climate outlook product from IRI

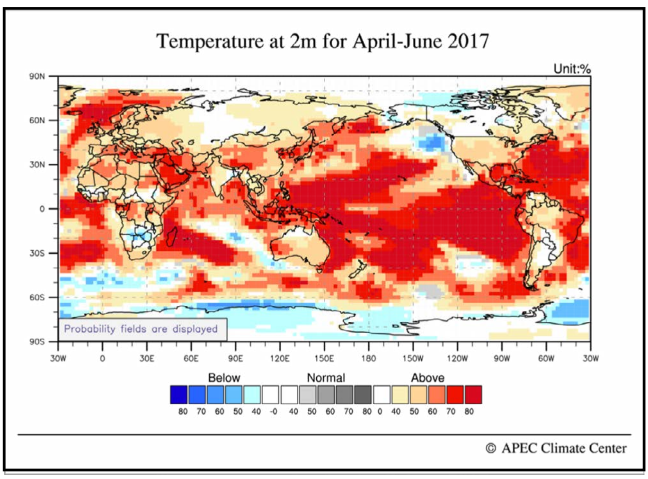

Figure 5: A climate outlook product from APEC Climate Center

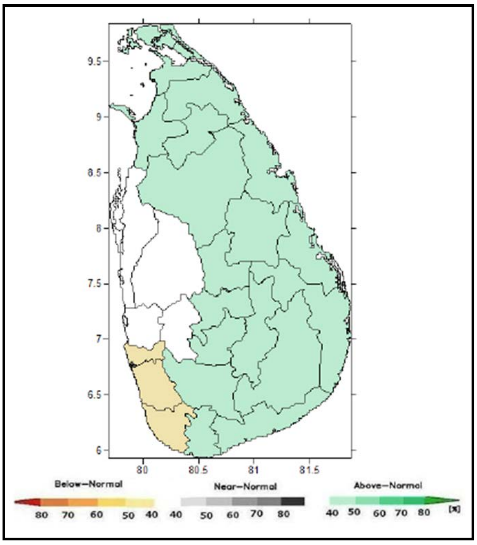

Figure 6: A Probabilistic Rainfall forecast product from Sri Lanka Meteorological Department

Discuss Specific examples for each category

Short-term:

1. Provision of schedules such as plant establishment, harvesting, fertilizer application, irrigation, etc.
2. Identification and selection of suitable varieties

Medium to long-term:

1. Prevention of damage due to weather and climate conditions and pests/ weeds on harvest
2. Building national safety stock
3. Market regulation
4. Food aid projections
5. Mitigation of food crises
6. Plan for fodder

Seasonal and multi-seasonal operational planning of major water resources systems require a careful evaluation of future likely scenarios of water and environmental conditions that influence management objectives. Using the climate outlook approach, seasonal and multi-seasonal hydrologic forecasts for balancing the needs of water supply, environment, flood control, and water quality enhancement can be achieved. Recent advances in long-range forecasting and the improved understanding of global phenomena such as El Nino-Southern Oscillation (ENSO) have allowed researchers to develop innovative water management approaches that make use of climate outlook forecasts.

Session 2.2.
Group Work

Group Work

Application of Climate Outlook for planning agricultural activities in the hypothetical Island of Utopia.

Following the instructions from the facilitator and using the given materials (landuse map, rainfall and temperature outlook maps)

- Manually digitize (Trace) to identify the extent of different cropping system using the landuse map;
- Super impose on outlook maps to extract rainfall and temperature probabilistic values in each agro-ecosystems;
- Develop adaptation and mitigation measures for each cropping system for next 3-month period.

Notes:

Module 3

Planning for Vulnerability Reduction and Resilience Building of Agro-ecosystems

Session 3.1.
Project Formulation for Design of Interventions to Build Resilience of Agro-ecosystems

Learning Objectives

At the end of this session, the participant would be able to:
- Briefly describe the sequential steps of project formulation and implementation
- Explain how to develop a problem tree and a solution tree for a selected ecosystem
- List a desirable sequence of approaches and tools to analyze and build resilience of an agro-ecosystem
- Describe the process of Stakeholder Analysis

1. Project Formulation

Interventions for vulnerability reduction and building resilience of agro ecosystems would be project based over an identified timeline. This must be done using inclusive participatory approaches with stakeholders and the beneficiary community.

Figure 1 depicts the accepted approach for project planning and implementation to reduce vulnerability from climate change.

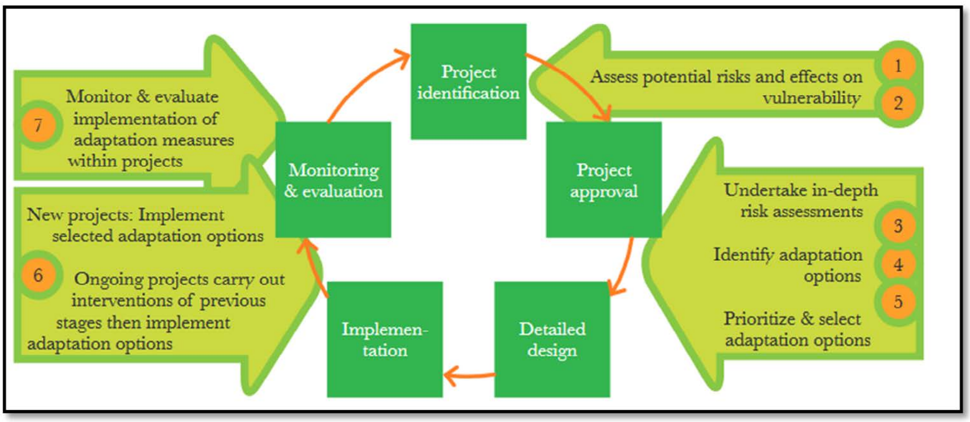

Figure 1: Project Formulation[1]

[1]*http://www.undp.org/content/undp/en/home/librarypage/environment-energy/climate_change/integrating_climatechangeintodevelopment/stocktaking-of-tools-and-guidelines-to-mainstream-climate-change-adaptation.html*

Prior to deciding what to do in order to enhance resilience of an ecosystem under study, it is important to undertake an analysis of the existing situation. There are many approaches to carry this out and tools to prioritize resilience building options. A combination of these approaches and tools is desirable for climate resilience building. Therefore, this training proposes the following sequence of intervention design.

1.1. Problem analysis (or situational and cause-and-effect analysis)

This focuses on the main problem the project wishes to address. Then attempt to find out the cause(s) for the problem, its effects and those affected by the effects. It identifies the situational problems in sectors relevant to the project and whether project implementation can be hindered by their presence. Therefore, it is good to review historical impacts of disasters and envisage possible climate related impacts on project outputs. These may threaten the sustainability of outputs.

A tool that is commonly used is the construction of a Problem Tree to show 'cause' and 'effect'. Figure 3 below is an example of a problem tree that has been constructed to understand wetland degradation[2].

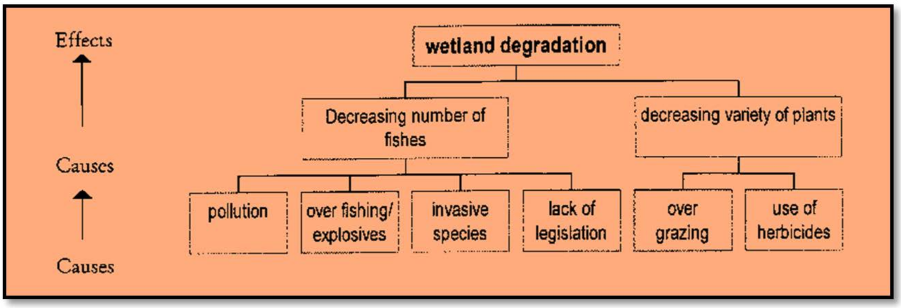

Figure 2: Example of a Problem Tree (http://www.ramsar.org)

1.2. Analysis of objectives (seeking of solutions)

Once the problem analysis is completed, a search for ways to fix the "causes" so as to eliminate the problem or reduce its impact can be undertaken. This can be done by way of an objective tree which would essentially address the "problems" (causes and effects) by converting them into "positive achievements" (ends and means), the "end" being the desired state at the completion of the project. Figure 3 below is an example of an 'objective tree' that follows the 'Problem Tree' in Figure 2.

1.3. Stakeholder analysis

The stakeholder analysis attempts to:

- identify the principal stakeholders
- investigate their roles, interests, relative power and capacity to participate in the project

[2]http://www.ramsar.org

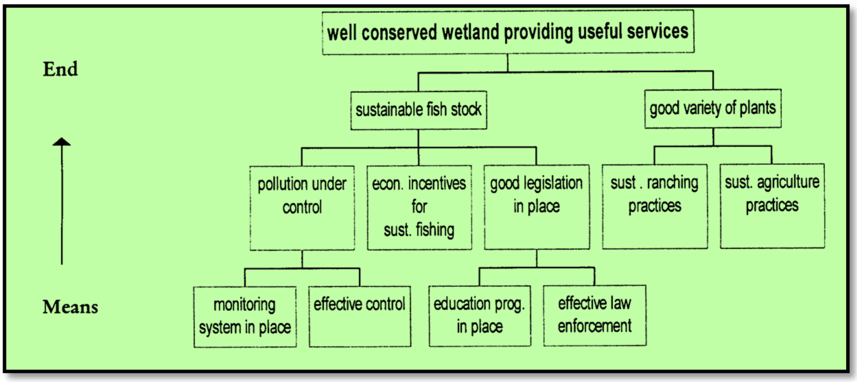

Figure 3: Example of an Objective Tree (http://www.ramsar.org)

- identify the extent of cooperation or conflict in the relationship between stakeholders
- interpret findings to facilitate activity design.

Stakeholders – Individuals or institutions that may directly or indirectly, positively or negatively, be affected by or affect and activity to be undertaken.

Beneficiaries - Those who benefit in whatever way by the implementation of the activity who may benefit directly or in some indirect manner.

Target Group(s) – The group / entity who will be directly and positively affected by the activity at the outcome level. This may include staff from the partner organizations.

Final Beneficiaries – Those who benefit from the activity in the long term at the level of society or sector at large e.g. "consumers" due to improved agricultural production and marketing.

Partners – Those who assist in implementing the activity (who are also stakeholders and may also be a target group)

Box 1: Stakeholders and Beneficiaries (Source: AusGuideline 3.3 (2005))

A useful tool here is a Venn diagram (See Figure 4).

At the center of the diagram will be a circle representing the Focal Point (FP) for resilience building of the Agro-ecosystem. Potential contribution of each relevant stakeholder identified is depicted through an individual circle. The name (or symbol) of each organization should be indicated on each circle or square. The position of the circle or square can illustrate the level of access to the stakeholder (closeness to the project).

Using the Venn diagram, one can analyze relationships and identify areas where it can be improved and where contributions can be enhanced for success of the project.

***NOTE:** In actual practice in a community, the information needed for this categorizations will come through inclusive participatory working with community members. You may also use tools such as Focus groups, Interviews, Questionnaire / Survey etc.*

Successful project implementation will depend on effective partnership building with stakeholders and beneficiaries. Local Governments and devolved administrative units will have a major influence of such outcomes. The diagram below is a sample of such a Venn diagram. The circles represent identified stakeholders. The distance between the focal point and a stakeholder circle represent the closeness of collaboration.

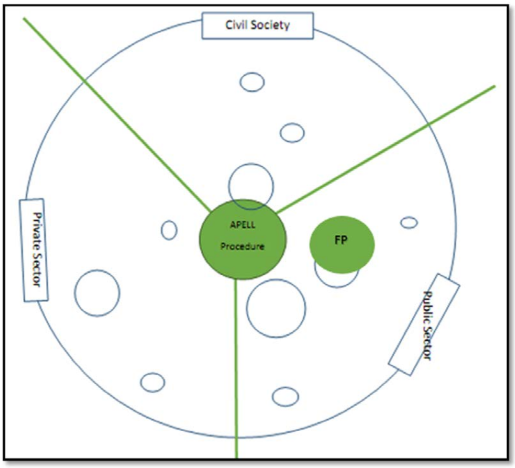

Figure 4: Venn diagram

1.4. Theory of Change Output (TOC)

Armed with the foregoing analysis, it is then desirable to develop a Theory of Change output which is *"the description of a sequence of events that is expected to lead to a desired outcome[3]"*. The Theory of Change is discussed in detail in a subsequent session. However all such desirable change pathways may not be achievable and therefore the most appropriate options may need to be screened out.

1.5. Analysis of Alternatives[4]

Desirable questions during this search for alternatives are given below:

- Should all of the identified problems and/or objectives be tackled, or a selected few?
- What is the combination of interventions that are most likely to bring about the desired results and promote sustainability of benefits?
- What is the likely capital and recurrent cost implications of different possible interventions and what can be realistically afforded?
- Which strategy will best support participation by both women and men?
- Which strategy will most effectively support institutional strengthening objectives?
- How best can negative environmental impacts be mitigated?

This can be carried out by using tools described for *Cost Benefit Analysis and Multi-criteria Analysis.* These tools will be discussed in detail during a subsequent session.

Assess alternative interventions in a workshop with identified stakeholders. Identify a number of assessment criteria against which alternative interventions can be ranked. Some useful criteria are suggested below:

- benefits to target groups – level of benefits, equity and participation
- sustainability of the benefits
- ability to repair and maintain assets post-activity
- total cost and recurrent cost implications
- financial and economic viability
- technical feasibility
- contribution to institutional strengthening and management capacity building
- environmental impact, and
- compatibility of activity with sector or program priorities.

There is usually more than one way to solve a development problem. *The aim is to find the best way(s) or a combination of ways.* The activities so selected needs to be within existing policy and legal framework of the country and therefore a review of relevant policy and legal framework is mandatory before finalizing activities to achieve set objectives.

1.6. Logical Framework Analysis (LFA)

A Logical Framework zooms in on the selected pathway(s) that appear viable in a multi criteria analysis, to achieve the desired state of change and will help in the effective monitoring of the project for their implementation. TOC and LFA would be discussed in detail in a subsequent sessions. Figure 5 below depicts the usefulness in combining the TOC approach and the LFA.

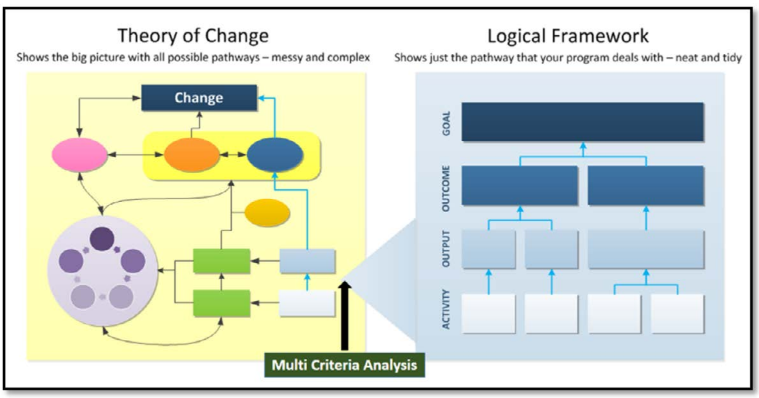

Figure 5: Combination of TOC, Multi-criteria Analysis and LFA[5]

[5]*Adopted from http://www.tools4dev.org/resources/theory-of-change-vs-logical-framework-whats-the-difference-in-practice/*

It is necessary to determine relevant indicators to monitor and evaluate project performance and success, Indicators should reflect the level of success needed in order to realize using a results-based framework. Indicators should be specific and tangible, measurable in quantity or quality, time and location; easy to collect; relevant and informative for decision-making purposes; and reliable. Related activities should be realistic. Most project formulations use the LFA.

Session 3.2.
Theory of Change

Learning Objectives

At the end of this session, the participant would be able to:
- Explain the Theory of Change Approach
- Describe Mapping of Pathways of Change
- Discuss the thinking behind the Theory of Change Approach

1. Concept of the Theory of Change

Theory of Change is ***"the description of a sequence of events that is expected to lead to a desired outcome[1]".*** It is also called the Theory of Change Approach.

It is thought as a process as well as a product. A process because people think about beliefs, and assumptions as how change can occur in the real world. A product because it maps out a logical sequence of inputs to outputs.

Five components are recognized for the approach:
- **Context** – This is a situation analysis about the problem that a project is trying to influence and change the state of being. This usually analyses the social, economic, environmental and political issues that may be relevant to the change that is sought.
- **The Long Term Effect** or the change desired and who will benefit.
- **The processes or inputs** needed in a sequential manner that is thought as needed to bring about the desired change.
- **Assumptions** that are made about the appropriateness of the processes and activities.
- **A Diagram and a narrative** that captures the components listed above.

Some advocate backwards mapping and connecting outcomes before the finalization of the product. Theory of Change conceptualizes a "real world" BIG picture, with possible pathways for a desired change which may be evidence- based or assumptions. TOC can include aspects of power shifts, how individuals influence others, the role of governance and civil society, as well as attitudinal changes that should precede behavioral shifts, etc.

As a first step, TOC participants discuss and reach consensus on the long-term change or changes. This will set the Goal or Goals. Then, participants agree on a pathway to reach the goal and this is mapped out indicating preconditions that may be required to bring about the desired change. The preconditions may be assumptions and it is necessary not to presume assumptions without laying it out for the map. The map visualizes the process to all stakeholders and their roles and responsibilities. Figure 1 below depicts how such a map may look like.

The assumption is that without each precondition in place, the long term goal cannot be achieved. It is necessary to define an indicator for each outcome or precondition in the pathway, as well as for the long term goal to be achieved. Figure 2 depicts these elements in a pathway of change.

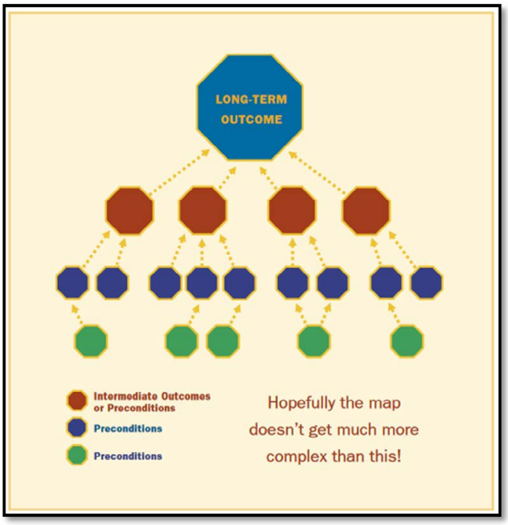

Figure 1: A Final Product of Pathway Mapping[2]

The TOC must also provide the assumptions and indicators that have been made that explains he pathway of change and spell out interventions that must be put in place to bring about preconditions.

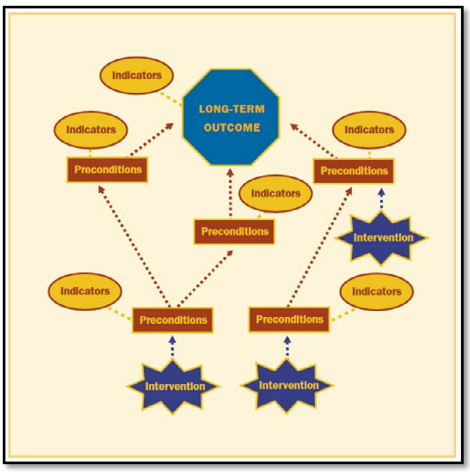

Figure 2: Elements in a Pathway of Change (Source: ibid)

[1]*http://mandenews.blogspot.co.uk/2012/04/criteria-for-assessing-evaluablity-of.html*
[2]*The Community Builder's Approach to Theory of Change: A Practical Guide (2009). www.aspeninstitute.org/…l-guide-theory-development/*
[3]*https://assets.publishing.service.gov.uk/media/57a08a66ed915d622c000703/Appendix_3_ToC_Examples.pdf*

A TOC diagram usually has 4 columns – **Inputs, Outputs, Outcomes and Impacts**, as shown in Figure 3 below is an example for a DFID Program.

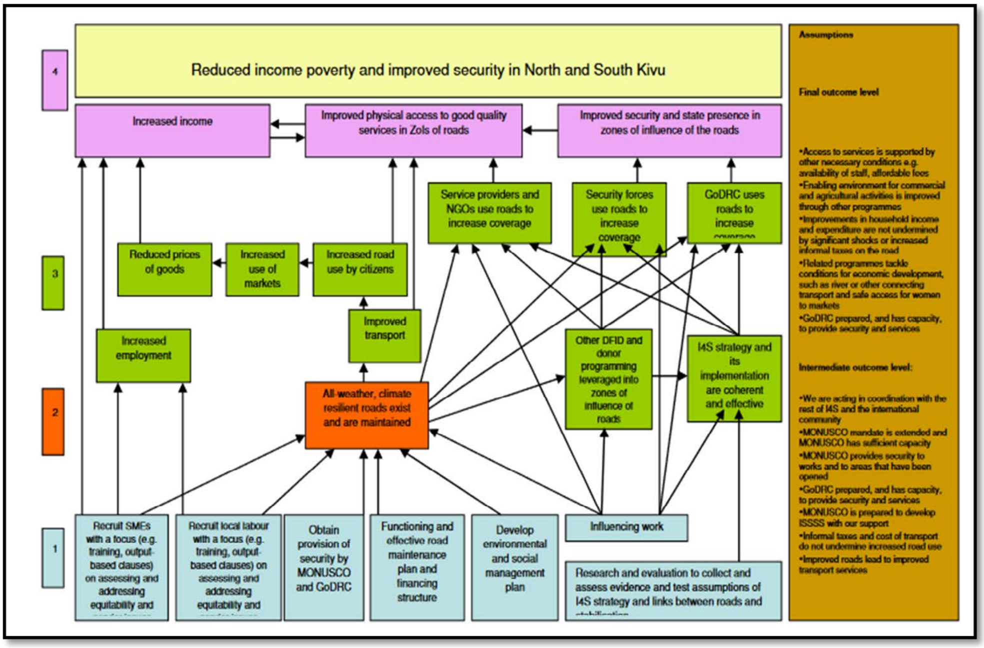

Figure 3: Example for Theory of Change (Roads in East DRC) (Adopted from example of DFID for Democratic Republic of Congo (DRC)[3])

In practice, a Theory of Change typically:

- Provides a big picture of issues relevant to the problem at hand.
- It shows all the possible pathways that may bring about a desired change to the current situation.
- Narrates how and why change happens… " do X then Y will change because…".
- It is presented as a diagram which provides easy to understand visual depiction. A narrative text may be added.
- The diagram has no pre-determined template or format

TOC is helpful as a tool for program design and evaluation. Figure 4 provides TOC thinking in a graphic form.

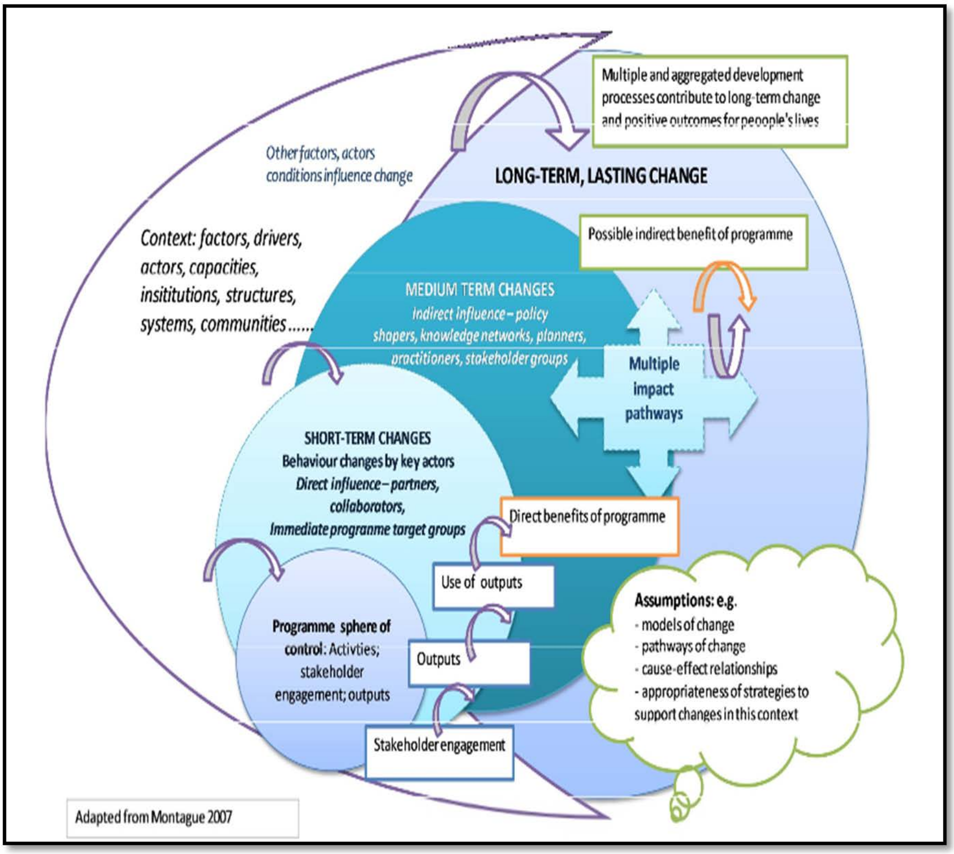

Figure 4: Theory of Change Thinking (Source: assets.publishing.service.gov.uk/…eview_VogelV7. pdf)

Session 3.3.
Group work on TOC

Notes:

Session 3.4.
Logical Framework Analysis (LFA)

Learning Objectives

At the end of this session, the participant would be able to:
- Explain the relationships bet
- LFM and its 'zigzag logic'
- Compile a LFM for an climate change adaptation activity

1. TOC vs LFA

Both Logical Frame Analysis (LFA) and Theory of Change (TOC) have the same purpose. They attempt to describe how a project (or program) can lead to results. In Session 3.1., it was stated that the TOC provides the "Big Picture" while LFA zooms in on specific pathways providing a more fine-tuned and orderly monitoring tool.

It was also suggested that a combination of approaches and tools will provide a more effective lens to look at climate change adaptation. The following Figure 1 is a recapitulation of these suggestions from Session 3.1.

visualizes the process to all stakeholders and their roles and responsibilities. Figure 1 below depicts how such a map may look like.

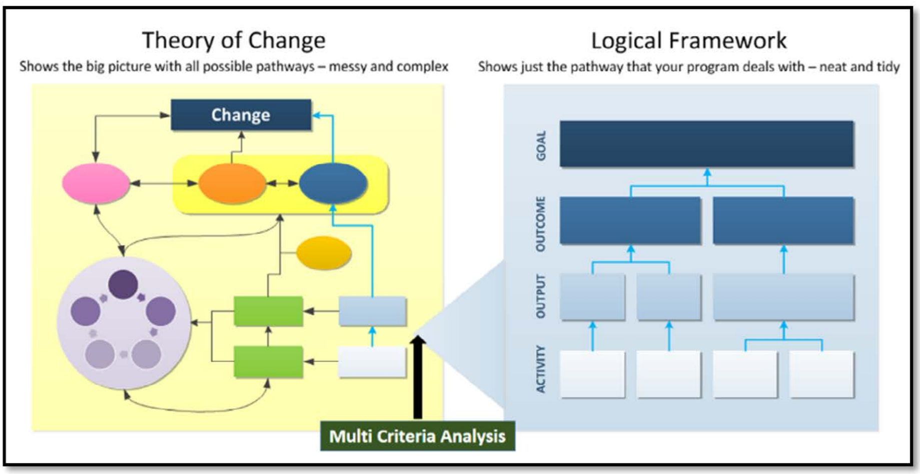

Figure 1: Combination of TOC, Multi-criteria Analysis and LFA[1]

[1]*Adopted from http://www.tools4dev.org/resources/theory-of-change-vs-logical-framework-whats-the-difference-in-practice/*

2. The 'Zigzag Logic of a Log Frame Matrix

Logical Frameworks are usually compiled using a **Log Frame Matrix (LFM)**. It has defined columns and rows as shown below. LFM is a logic model and a planning tool exhibiting linear cause and effect relationships. Completing the Assumptions / risks column may become challenging. However if the 'zigzag logic' described below is followed carefully, assumptions realistic and relevant to outputs and outcomes may be formulated.

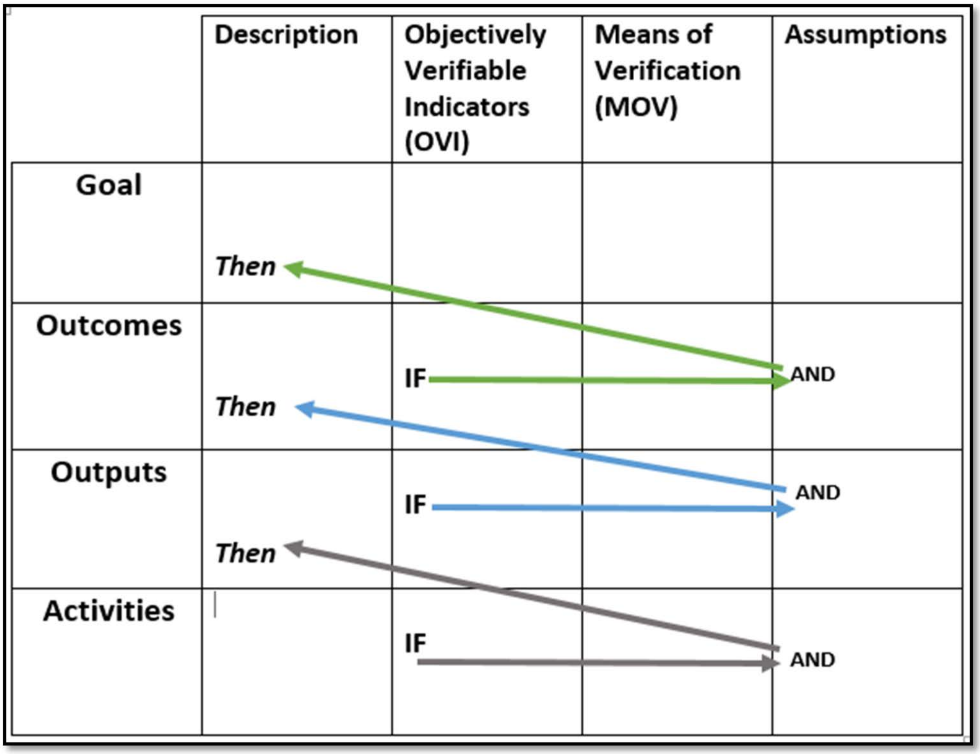

Figure 2: Log Frame Matrix and its "Zigzag Logic"

IF these **activities** are undertaken **AND** the **assumptions** are true **THEN** these **outputs** will be produced.

IF the **outputs** are created **AND** the **assumptions** are true **THEN** the **outcome** will be achieved.

IF the **outcomes** are achieved **AND** the assumptions are true **THEN** the **goal** will be achieved.

The same 'zigzag logic' is used upwards to build each higher level row from the bottom row, until the final impact (Goal) will be reached. Log Frame measure each activity, output, outcome and goal using a measurable indicator or indicators. It facilitates more thinking into the planning process.

Upward pathway across each rows is similar to traversing a change pathway in a TOC. Many LFA do not use the inputs. But this is flexible. Note that donors may provide a matrix which may use different terms.

LFM shows the Terms of reference of an intervention. For every activity/ output/ purpose and goal it provides a description, indicators, means of verification and assumptions. The description is just the narration of the every row like what was done for each change pathway in the TOC. However the rigid linearity and sequential order of the LFA is considered as a disadvantage by the proponents of TOC.

2.1. Objectively Verifiable Indicators (OVIs)

Objectively verifiable indicators define the performance or achievement to be reached at each row. They should be measurable through observation. Indicators are independent at different levels. The same indicator cannot be used in two different rows. Indicators are useful as a basis for monitoring and evaluation.

2.2. Means of Verification (MOVs)

They spell out the source to find the data to verify whether the indicator has been achieved. Setting an MOV involves answering several questions such as:

- What exactly is the information necessary?
- Where is it available?
- How reliable is the source?
- What cost and time will be needed?
- Etc.

2.3. Assumptions

Assumptions are variable factors that may be beyond the control of the project implementers. However these are necessary to proceed to the next level of the 'zigzag logic'.

3. A Sample LFM for Discussion

	Description	VOI	MOV	Assumption
Goal	Farming livelihood made sustainable despite the salinity intrusion into the target coastal area	Income levels of households back to normal levels.	Household survey	All stakeholders of the crop value chain committed to sustaining the new variety
Outcome	Agricultural productivity and output increased and sustained.	The yield (in metric tons per hectare) of the crop increased from current average to yield level before salinity intrusion	District department of agriculture records	Farmers have adopted the new variety and are conversant with its Culture requirements
Output	Loss of harvest prevented due to salinity sensitive crop variety	Crop yield hike compared to the baseline level	Reports of the Agricultural Extension Office	Consumers find the new crop variety as acceptable for consumption
Activity	Provide a salinity tolerant crop variety to affected coastal agro-ecosystems which suffer decrease in yield due to crop sensitivity to increase soil salinity.	New crop seeds are made easily accessible Through extension services	% farmers in each area adopting the new crop variety	Farmers are willing to replace traditional varieties with the new crop variety

Table 1: Example of an LFM for Climate Change Adaptation

Session 3.5.
Group work on LFA

Notes:

Session 3.6.
Introduction to Cost Benefit Analysis and Multi Criteria Analysis

Learning Objectives

At the end of this session, the participant would be able to:

- Describe Cost Effectiveness Ratio, Cost Benefit Ratio and Multi-criteria Analysis to choose between adaptation options

1. Choice of Optimal Adaptation Options

Choice of best option(s) needs to be made based on the cost of alternative adaptation option compared against their benefits. Adaptation costs are the costs for planning, preparing for, facilitating, and implementing adaptation measures, including transition costs, while adaptation benefits are the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures[1].

EU funded research program MEDIATION[2], which is a platform for sharing a diverse set of methods and tools for assessing climate change impacts, vulnerability and adaptation (2010) observes that it would be useful to supply information on both costs and benefits within an adaptation decision framework, allowing decision makers to make informed decisions between options, allowing trade-offs and providing a means to justify decisions.

UNFCCC study (UNFCCC, 2010)[3] on the 'Potential costs and benefits of adaptation options' reports on the lack of detailed analyses of the costs and benefits of adaptation, in a form that is relevant to decisions on public funding.

Adaptation Finance Gap Update by UNEP (2015)[4] has made the following observations on factors that influence cost estimates (See Box 1).

1.1. Methodology for estimating cost of Adaptation

UNFCCC (2010)[5], has summarized a broad range of methods identified by IPCC (2007), for adaptation assessment. These are listed below.

- Scenario-based approaches, where climate risks are scoped qualitatively or quantitatively and adaptation options are identified.

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[1]*IPCC AR4, (2007)*
[2]*http://climate-adapt.eea.europa.eu/metadata/publications/review-of-available-methods-for-cost-assessment (2010)*
[3]*unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf*
[4]*http://web.unep.org/adaptationgapreport/content/adaptation-gap-reports*
[5]*unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf*

- Technological assessments, which extend to include future adaptation options (that differ from those currently available) under alternative socio-economic scenarios.
- Normative policy assessments, which use the outputs of vulnerability and/or risk assessments to assess acceptable adaptation options or strategies.
- Risk management methods, which combine current risks to climate variability and extremes with projected future changes, using alternative decision support tools to assess adaptation.
- Anthropological and sociological methods, which identify learning in individuals and organizations and the processes needed to effectively adapt to climate change risks.
- Adaptive Capacity Assessments, which considers investment in adaptive capacity in a way similar to adaptation options.
- Cost-Benefit Analysis (CBA), where the benefits and costs of adaptation are expressed in monetary terms, and the net benefits or costs calculated.
- Non-formalized cost-benefit analysis, where costs and benefits are compared, using monetary and non-monetary terms as part of multi-attribute analysis.
- Cost-effectiveness Analysis (CEA), which is often used to assess alternative adaptation options or the least-cost path to reaching a given target (e.g. a predefined threshold level).
- Multi-criteria analysis (MCA), which allows consideration of quantitative and qualitative data together using multiple indicators.
- Portfolio Theory, which borrows principles from financial investment to maximize the expected rate of return for a portfolio as a whole rather than individually.
- Participatory techniques, which is based on analysis of direct participatory approaches. The most typical methods for appraising adaptation options (decision support) used in the literature include Cost Effectiveness Analysis (CEA), Cost-Benefit Analysis (CBA), and Multi-criteria Analysis (MCA) though other approaches have been adopted.

Issues with Methodology

Methodologies for costing adaptation measures have issues dealing with long-term risk, discounting, and uncertainty of CC predictions.

Some other issues include:

- Challenges in defining the future socio-economic development.
- The separation and attribution of future climate change.
- The level of spatial disaggregation.
- The linkages with mitigation.
- The challenges in assessing benefits, and even costs, for many nontechnical (soft) or non-market adaptation options.

Key factors that influence adaptation cost estimates and explain differences between them

Estimates of the costs of adaptation are influenced by the goal or target chosen, and the degree of trade-off between the impacts of climate change, the costs of adaptation, and the residual costs after adaptation. This choice involves perspectives on economic efficiency versus equity.

The costs of adaptation depend on the coverage of sectors and risks: more comprehensive studies will produce higher adaptation cost estimates.

Cost estimates differ with the future emissions pathway and associated projected temperature increases. Estimates are higher, even in early years, for higher warming scenarios. Costs also increase if uncertainty from future warming scenarios and climate model uncertainty is considered. However, costs are also influenced by future socio-economic development, and this can reduce future costs in some cases.

There will be limits to adaptation and the potential for adaptation to substitute for mitigation. Potential limits include physical and ecological limits, technological limits, financial barriers, information and cognitive barriers, and social and cultural barriers. These are not yet factored into cost estimates and have the potential to increase the estimates, though the knowledge base, and thus the scale of the effect, is largely unknown.

Costs are determined by the existing adaptation gap, which is higher in developing countries. The costs of addressing this gap may not be classified as adaptation only as there are significant overlaps with development. However, unless they are tackled first, they reduce the effectiveness/increase the costs of adaptation.

So far, the primary focus has been on assessing the costs of planned proactive adaptation, primarily undertaken by the public sector. This excludes or omits household or private adaptation: inclusion of this autonomous adaptation increases the estimated costs of adaptation, potentially very significantly.

Most current studies are based on technical (engineering) costs. Analysis shows these underestimate costs due to various opportunity and transaction costs. There are also additional costs associated with implementation due to governance challenges. Countering this, non-technical options, learning and innovation all have the potential to reduce future costs.

Box 1: Adaptation Finance Gap Update

1.2. Method of Cost Assessment

1.2.1. Cost effectiveness analysis (CEA)

This description has been adopted from the "Review of available methods for cost assessment" (2010[6]). The method assesses and compares the costs (financial costs, and wider opportunity costs) of alternative adaptation options. CEA has been applied to sectoral assessment of many national studies e.g. health, freshwater systems, coastal and river flood risks, extreme weather events and biodiversity and ecosystem services.

Cost effectiveness analysis (CEA), as defined by the IPCC, "takes a predetermined objective (often an outcome negotiated by key stakeholder groups in a society) and seeks ways to accomplish it as inexpensively as possible" (Ahmad et al. 2001[7]). The aim of CEA is to find the least costly option or options for meeting selected physical targets.

The easiest way to think about CEA is to assume that there is a single indicator of effectiveness, E, and this is to be compared to a cost of C. The usual procedure is to produce a cost-effectiveness ratio (CER): CER = E/C. Table 2 below shows how this is achieved for a hypothetical example.

[6]*Review of available methods for cost assessment — Climate-ADAPT climate-adapt.eea.europa.eu/metadata/.../review-of-available-methods-for-cost-assess...*
[7]*http://www.unep.org/provia/portals/24128/Guidance_Prototype/toolbox/cea.html*

Option	Cost (C)	Effectiveness (E)	E/C
Option 1	$10,000	$25,000	2.5
Option 2	$1,000,000	$500,000	0.5
Option 3	$1,010,000	$525,000	0.52

Table 1: Comparison of CER for different Options

If CER is > 1, then the option is beneficial. In the example above Option 1 is the desirable option to select.
Cost effectiveness cannot be used to compare adaptation between sectors, because there are no common metrics.

Assessing cost-effectiveness in practice will be complex. If adaptations are implemented unwisely without proper consideration, adaptation responses may actually enhance the effects of climate change. This is called "mal-adaptation". Choice of cost-effective adaptation measure which can cause no harm or no regret measures is the desirable approach.

There are constraints in prioritizing adaptation options according to cost-effectiveness:

- Adaptation is determined strongly by local conditions,
- Adaptation is sector specific and considers sector specific impacts. Therefore inte-sectoral comparisons are not possible.

There are no standardized metrics in relation to what a given level of adaptation achieves - it varies according to the type of impact being considered. There may be drivers other than climate change for an observed phenomenon that are difficult to separate out.

There may also be differences in magnitude of the adaptation response achieved according to whether implementation is proactive or reactive, or according to the specific time period when the measure is implemented, both in terms of costs, but also in relation to the adaptation benefits achieved.

Furthermore, the effectiveness of adaptation relies on adaptive capacity, exposure to risk (vulnerability) and sensitivity which may vary based on local context. It is also dependent on the discount rate used in calculations, especially for longer-term options.

In practice, CEA tends to proceed with indicators of effectiveness chosen by experts. Rationales for using expert choices are:

- Experts are better informed than individuals, especially on issues such as habitat conservation, landscape etc.
- Securing indicators from experts is quicker and cheaper than eliciting individuals' attitudes (Pearce et al., 2006[8]).

However, expert opinion may vary from individual to individual.

1.2.2. Cost Benefit Analysis (CBA)

This description has been adopted from *"Review of available methods for cost assessment"* (2010[9]). In cost benefit analysis (CBA), outputs are explicitly valued in money terms. If the economic benefits (B) of adaptation such as the reduction in climate change impacts (or the potential positive consequences) outweigh the costs (C), then there are net benefits – if not, then this potentially leads to mal-adaptation. This leads to the decision of accepting or rejecting an option. This overarching principle is important because resources need to be allocated efficiently between different adaptation strategies and between adaptation and mitigation strategies. This can be done only if costs and benefits of the different options are clearly determined.

CEA compares the costs of alternative ways of providing similar kinds of outputs. A matrix may be used for Cost-Benefit Analysis as described below (similar to Cost Effective Analysis).

Option	Cost (C)	Benefit (B)	B/C
Option 1	$10,000	$25,000	2.5
Option 2	$1,000,000	$500,000	0.5.
Option 3	$1,010,000	$525,000	0.52

Table 2: Comparison of CBR for different Options

- In many cases benefits will certainly exceed costs. Optimal policy to live with climate change will be somewhere between benefits exceeding costs and non-cost-effective measures (i.e. 'cost- effective and proportionate').
- Benefits are defined as increase in human well-being (utility) and costs are defined as reductions in human wellbeing.
- For a project or policy to be justified on cost-benefit grounds, its social benefits must exceed its social costs. Hence CBA is also called societal CBA, if cost and benefits are assessed from the perspective of society as a whole.
- The initial step of CBA is to determine whose costs and benefits and the time horizon over which costs and benefits are counted.
- Second, CBA has to consider the time-preference through the process of discounting because individuals have preferences for when they receive benefits or suffer costs.

[8]*Pearce, D. Atkinson G. and S. Mourato. (2006). Cost-Benefit Analysis and the Environment: Recent developments. OECD.*
[9]*Review of available methods for cost assessment — Climate-ADAPT climate-adapt.eea.europa.eu/metadata/.../review-of-available-methods-for-cost-assess...*

Costs and benefits are rarely known with certainty so that risk (with probabilistic outcomes) and uncertainty (when no probabilities are known) also have to be taken into account. The decision rule for comparing costs and benefits is the net benefits criterion. A standard CBA involves calculating the present values of the social costs (PVC) and benefits of a project or an adaptation option (PVB), and their difference (*Net present value* NPV) or their ratio (B/C).

***If B / C is greater than 1* then the project adds welfare to society.**

All projects with a positive NPV should, in principle, be undertaken because they add to the welfare of society, but budget constraints prevent this from happening. A project with a positive NPV may not proceed because an alternative project has a higher NPV. When there are a number of projects and programs available to decision makers with a limited budget, it is necessary to rank projects. The use of CBA can be limited, primarily because of the partial availability of data on the costs and benefits of adaptation options.

Further, CBA fails to account for those costs and benefits that cannot be reflected in monetary terms, particularly such as ecological impacts, as well as concerns that influence welfare, such as peace and security.

Subject to this qualification, it can be applied to decisions in some sectors for certain types of adaptation options (e.g. technical measures for flood prevention), or in sectors where there is a major private sector involvement (UNFCCC, 2010[10]).

The advantages of CBA as a tool for guiding public policy are as follows:

- It considers the gains and losses to all members of the society on whose behalf the CBA is being undertaken
- It values impacts in terms of a single, familiar measurement scale – money – and can therefore in principle show that implementing an option is worthwhile relative to doing nothing
- The money values used to weight the relative importance of the different impacts are based on people's preferences generally using established methods of measurement.

1.2.3. Multi criteria analysis (MCA)

This description has been adopted from "Multi-criteria analysis: a manual - LSE Research Online[11] (2009). MCA applications usually considers a combination of criteria that are valued in monetary terms, and others for which monetary valuations do not exist. This is its advantage over the other methods. Multi-criteria analysis assesses choice of options by reference to a set of objectives that the decision making body has identified, and for which it has established measurable criteria In simple circumstances, the process of identifying objectives and criteria may alone provide enough information for decision-makers.

According to UNFCCC[12], MCA or multi objective decision making is a type of decision analysis tool that is particularly applicable to cases where a single-criterion approach (such as cost-benefit analysis) is inadequate, especially where significant environmental and social impacts cannot be measured in monetary values. MCA allows decision makers to include a full range of social, environmental, technical, economic, and financial criteria.

The actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Different environmental and social indicators maybe developed side by side with economic costs and benefits.

Key output is a single most preferred option, but when several options are compared, more than one option may turn out to be desirable and therefore chosen for implementation. An Example of a simple MCA is given in Box 2 below.

A simple example of MCA is illustrated below. This aims to rank three alternative crop varieties A, B and C for coastal agroecosystems impacted by salinity intrusion. The criteria are: (i) increase in yield (ii) Consumer acceptance (iii) Tolerance level for salinity. These are used to evaluate and rank the crop varieties. The first step is to provide scores for each of the criteria related to these alternatives, as the example below shows.

Criteria / Option	Crop A	Crop B	Crop C
Increase in yield	5	3	2
Consume acceptance	2	4	3
Tolerance level for salinity	3	1	4

Table 3: Scores per criteria per alternative: a hypothetical example

Note: 5=very high 4=high 3=average 2= low 1=very low

Selected weights are then assigned to each of the criteria. For this example, the assumption is that all three assume equal importance to the farmer's choice. Therefore equal weights for all three criteria are assigned, i.e. 0.333 for each. However in many cases, the different criteria assume different importance levels and may therefore be assigned different weights. The weights assigned enables the calculation of the weighted scores for each of the alternatives. The weighted scores for this example are as follows:

[10] *unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf*
[11] *http://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf*
[12] *http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5440.php*
[13] *Decision Support Methods for Climate Change Adaptation Summary of Methods and Case Study Examples from the MEDIATION Project, www.iee.usp.br/.../Decision_Support_Methods_for_Climate_Change%20 Adaption(1)*

- Alternative A: 0.33*5+0.333*2+0.333*3 = 3.33
- Alternative B: 0.33*3+0.333*4+0.333*1 = 2.664
- Alternative C: 0.33*2+0.333*3+0.333*4 = 2.997

Criteria / Option	Crop A	Crop B	Crop C
Increase in yield	5	3	2
Consume acceptance	2	4	3
Tolerance level for salinity	3	1	4
Total Weighted score	***3.33***	***2.64***	***2.997***

Table 4: Table with the weights per criteria

Note: 5=very high 4=high 3=average 2= low 1=very low

Table 2 shows that alternative A would be preferred, because it has the highest total score. However, the other two options may also be beneficial depending on local context e.g. consumer acceptance.

Box 2: Example of MCA[13]

1.2.4. Example of MCA for Adaptation in the Netherlands[14]

An example of a multi criteria analysis for adaptation in the Netherlands is summarized, based on De Bruin et al. (2009)[15] and Van Ierland et al. (2007)[16]. The analysis started with a typical climate change scenario developed by the Royal Netherlands Meteorological Institute for the period up to 2050. Adaptation options were identified in workshops for different sectors, namely agriculture, nature, water, energy & transport, housing & infrastructure, health, and recreation and tourism. Experts on spatial planning and adaptation to climate change as well as public and private stakeholders were involved in the identification and ranking of the adaptation options, including representatives from different research institutes, NGOs, universities and Ministries.

The next step was to score and weight these adaptation options. The options (see Table 5 for examples for the agricultural sector) were given scores with respect to the following priority criteria:

- the importance of the option in terms of the expected gross benefits that can be obtained;
- the urgency of the option, reflecting the need to act soon and not later;
- the no-regret characteristics of the option (it is good to implement, irrespective of climate change);
- the co-benefits to other sectors and domains; and
- the effect on climate change mitigation (for instance through changes in land-use that reduce emissions of greenhouse gases as a side effect).

In defining the criteria all relevant criteria have been included, operational (each option can be judged against each criterion), mutually independent (options are independent of each other from one criterion to the next), contain no double counting and are consistent with effects occurring over time.

However, not all criteria are completely mutually exclusive; the no-regret and cost-benefit criteria are closely related to each other. The scoring is based on subjective expert judgement and has been discussed in a workshop with external experts to validate the scores. Experts were invited with a broad overview of the problem of adaptation to make the ranking because the adaptation options cover many different aspects and sectors of society, and the ranking requires the capability to compare the various options across these sectors. Specialized stakeholders representing a specific sector would not be able to make this comparison across sectors, but of course they were valuable in identifying adaptation options relevant to their sector (See Table 5).

Nr.	Sector	Adaptation option	Importance (40%)	Urgency (20%)	No regret (15%)	Co-benefits (15%)	Mitigation effect (10%)	Weighted sum
34	Nature	Integrated nature and water management	5	5	5	5	4	4.9
35	Nature	Integrated coastal zone management	5	5	5	5	4	4.9
40	Water	More space for water – a) Regional water system, b) Improving river capacity	5	5	5	5	4	4.9
41	Water	Risk based allocation policy	5	5	5	5	4	4.9
65	Water	Risk management as basic strategy	5	5	5	5	4	4.9
68	Water	New institutional alliances	5	5	5	4	5	4.9
87	Housing Infra.	Make existing and new cities robust – avoid 'heat islands', cooling capacity	5	5	4	5	4	4.8
75	Energy & Transport	Construct buildings with less need for air-conditioning/heating	5	4	5	4	5	4.7
84	Energy & Transport	Change modes of transport and develop more intelligent infrastructure	5	5	4	4	5	4.7
28	Nature	Design and implementation of ecological networks (The National Ecological Network)	4	5	5	5	4	4.5

Table 5. The top ten options for the Netherlands based on ranking with criteria weighting for importance, urgency, no regret, co-benefits and mitigation effect – high scores indicate high priority. Note: high scores indicate high priority to implement the option

[14]*ibid*

[15]*De Bruin, K. R. B. Dellink, A. Ruijs, L. Bolwidt. A. Van Buuren. J. Graveland. R. S., De Groot. P. J. Kuikman. S. Reinhard. R. P. Roetter. V. C. Tassone. A. Verhagen. and E. C. Van Ierland. (2009). 'Adapting to climate change in the Netherlands: An inventory of climate adaptation options and ranking of alternatives', Climatic Change 95 (1–2), 2009, 23–45.*

[16]*Van Ierland EC. de Bruin K. Dellink RB. Ruijs A (eds). (2007). A qualitative assessment of climate adaptation options and some estimates of adaptation costs. Reports on the Routeplanner projects 3, 4 and 5 (Routeplanner deelprojecten Decision Support 3, 4 en 5), Wageningen UR. Available at www.enr.wur.nl/UK/Routeplanner+Report*

As weighted sums are well above one, all options appear beneficial.

Key strengths

- Can combine quantitative and qualitative data, using monetary and non-monetary units, and can therefore consider a much wider set of criteria, even where quantification is challenging or limited.
- The method is relatively simple and transparent, and can be done at relatively low cost and within a limited time.
- Expert judgement can be used very efficiently.
- It involves stakeholders and can be based on local knowledge.

Potential weaknesses

- Results need further interpretation and elaboration in more detailed studies.
- Different experts may have different opinions and will provide different scores, i.e. there is a degree of subjectivity involved.
- Stakeholders may have lack of knowledge and can miss important options.
- It may be difficult to give consistent scores to the alternatives.
- Analysis of uncertainty often highly qualitative.

Box 3: Elaborates Strengths and Weaknesses of MCA[17]

[17]Decision Support Methods for Climate Change Adaptation Summary of Methods and Case Study Examples from the MEDIATION Project, www.iee.usp.br/.../Decision_Support_Methods_for_Climate_Change%20 Adaption(1)

Notes:

Module 4

Synthesis of Learnings through a Scenario Based Exercise

Session 4.1.
Introduction to Scenario Based Group Work

Case Study for Desk Top Simulation for Agro-ecosystem Resilience for Sri Lanka and Vietnam

The Scenario

Consider the legal, institutional frameworks for Disaster risk reduction and Climate Change Adaptation for the hypothetical scenario below as similar to your own country.

A team of researchers from a university studying ecosystem resilience decided to carry out a study of a coastal area called **Sam** of about 2000 hectares accommodating about 1000 households. 40% livelihoods centered on shallow water (Reef) fishing around the extensive coral reef. About 5% were engaged in providing tourism to the coral reefs using glass bottomed boats. About 30% were paddy / vegetable farmers. They are getting irrigation water by tapping illegally into the local river which flow to the sea through an estuary with an extensive mangrove forest and wetland. In recent years, there has been an escalation of riverine floods affecting farmland.

The mangrove area has for the last five years been used for shrimp framing by an influential businessman, which has resulted in extensive cutting down of mangroves and effluent pesticides flowing into the sea through the river that runs through the estuary. This has deteriorated water quality of the estuary and the team suspects this may be a source of pesticide residues for agricultural and fishery products.

Parts of the wetland had to be filled up for two hotels catering to foreign tourists due the aesthetic scenery of the area. Construction of the hotels has led to the destruction of several sand dunes which acted as buffer for storm surges.

Findings of the research group through participatory methodology is given below.

The research team believes that there is a possibility of sea level rise and increase in temperature due to climate change and emphasize the need for climate change modelling for the country to understand local impact and to take necessary action.

Their findings for Sam also reflect possibility of climate change impact.

- The frequency of storms surges due to high wind has significantly increased coastal flood events and now they reach further inland.
- Paddy fields are becoming uncultivable due to increased salinity leading to a reduced harvest and income levels. Increased storm surges also contribute to loss in yield.
- During the dry season, there is increased salinity intrusion upstream, which forces the coastal dwellers to go further inland for drinking water supplies from the river.
- Illegal tapping of the river for irrigation reduces the flow of sand sediments that contribute to building of the shoreline and the flow of nutrients into the shallow sea which contribute to the productivity of the reef ecosystem.
- Increasing trend of riverine floods has affected income levels of farmers due to inundation of cropland.
- The drop in income levels had increased cutting down of mangroves to sell as firewood.
- Level of malnutrition in the under 5 year children has increased.
- Coral reef damage has increased due to anchoring of boats on the reefs and tourists trampling on reef.
- There is coral bleaching which scientist attribute to increase in temperature due to climate change.
- Oil leakages and dumping of used engine oil is gradually destroying the reef.
- There is a significant loss in the reef fish harvest increasing the poverty level of the fishing community.
- There appears to be increasing levels of conflict between the glass bottomed boaters and local fisherman due to blame on the coral reef tourism for loss in fish harvest and for damaging fishing gear by passing too close to fishing activity.
- Community members have conflicts with the two hoteliers for limiting access to parts of the estuary and beaches and the rumors that they are trying to fill more wetlands for hotel expansion.
- The hotels pump out untreated sewage through a drain pipe into the sea.
- The local government shows no interest in rectifying livelihood threats due to lack of awareness of national legal statutes and environmental protection.
- There is very low understanding in all concerned about the value of the ecosystem services and the need to conserve these for livelihood sustainability.

Using this information Develop

- A Problem Tree
- Objective (Solution)
- Analyze the status quo of stakeholders for the interventions to re-build the resilience of the coastal area using a Venn diagram with special focus on local government and decentralized administrative units who could contribute to rectifying problems through policy innovations.
- Develop a Theory of Change based on the problem tree and solution tree.
- Selecting one intervention that you subjectively prioritize, develop a LFA.
- Develop a Time-bound Action Plan for LFA
- Suggest possible ways of influencing Local Government to intervene.
- Make a 20-minute presentation.

Notes:

Annex

Exercises for the Workshop Sessions

The following exercises to be presented at the end of session's group work.

Module 1

1. ***Sessions 1 & 2***
    - These two sessions will be devoid of group work as these are introductionsto basic concepts. However the participants will have opportunity to exercise their understandings in consequent group work.
2. ***Session 1.3***
    - In group consensus, list the ecosystems that are relevant to the social component in the scenario provided.
    - Draw a graphic depiction of the Social Ecological System given in the scenario.
3. ***Session 1.4***
    - In group consensus, list the ecosystem services provided by the ecosystems identified.
    - Discuss possible threats for their sustainability.

Module 2

4. ***Session 2.1***
    - Based on the climate Outlook and land use map provided, the group will develop adaptation and risk mitigation measures for the each cropping systems (rice, coconut, vegetable, etc.) for next 3 months period.

Module 3

5. ***Session 3.1***
    - Using the scenario provided, develop a problem tree and an objective tree.
6. ***Session 3.2***
    - Collating outputs of the previous group work, formulate a Theory of Change for the SES depicted in the given Scenario.
7. ***Session 3.3***
    - Prioritize your interventions agreed upon for the TOC, and select a priority intervention and develop a Log Frame Analysis (LFA) for its implementation.
8. ***Session 3.4***
    - Develop a Cost-Benefit Analysis for the intervention chosen for your LFA.

Module 4

9. ***Final Scenario Based Group Work***
    - By synthesizing the outputs of previous exercises, formulate a project for implementation of the chosen intervention including a monitoring and evaluation component.
    - Develop a time-based action plan for the project.

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