Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia

Climate Change Education Modules

Module I: Basic of Climate Change

Module II: Cause and Effect of Climate change

Module III: Climate Change Adaptation

Module IV: Climate Change and Water Resource Management

Prepared By: Mr. Thav Sopheak

Project Leader

Email: sopheakthav@yahoo.com

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MODULE I:
BASIC OF CLIMATE CHANGE

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Introduction to the Training Manual

Background and Aims of Training: This training manual supported 4-day Training of Training on **"Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia"**. The development of a training manual and the training of trainer program on basic of climate change is the critical to achieving the objectives of the training in building capacity to adapt to climate change.

Purpose of this Training Manual: This training manual seeks to provide knowledge of and training in basic of climate change. In this context the trainee will learn the concept of climate change with emphasize of climate change history.

How the training materiel was developed: There are many sources for developing this manual. Internet is the major source including www.who.org and www.oaresciences.org which is the international Journals for best matching literature review. However, since the scope of this manual is mainly demonstrate in the context of Cambodia; it is very important to access the documents from Ministry of Environment for documentation and also others research as well.

How to use this manual: This manual can be used for additional documentation for raising-up general knowledge in basic of climate change. It does really benefit for those who want to know about basic of climate change and other researches. Before reading this manual please doesn't forget to go through with this Introduction.

Module I: Basic Climate Change

The purpose of this training module is to provide trainees in agricultural universities/institution with KSA (Knowledge, Skills, and Attitude) on climate change, including causes and effects of climate change.

Target Group:

Lecturers, researchers, and staffs in agricultural universities/institutions in Cambodia who interest on climate change.

Learning Outcome:

At the end of the module, the participants will be able to:

1. Understand the climate change
2. Understand the cause by anthropogenic (human activities) and natural on climate change.
3. Understand the effect and impact of human activities of climate change on ecosystem, human and other values.
4. Understand the attitude of the climate change solutions.

Learning Objectives:

1. To provide the readers understanding clearly on the climate change
2. To provide readers to understand on the cause by anthropogenic (human activities) and natural on climate change.
3. To provide readers to understand on the effect and impact of human activities of climate change on ecosystem, human and other values.
4. To provide the readers to understand clearly about the attitude of the climate change solutions.

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1. Introduction to Climate Change

We are living at a remarkable moment in the history of the human species. Human population size, and the extent and nature of our economic activities are now so great that the gaseous composition of the lower and middle atmosphere (the troposphere and the stratosphere) has begun to change. This is likely to affect the world's climate, many other of the world's natural system, ground-level exposure to ultraviolet radiation (UVR), and indeed, all life on earth.

Rapid increase this century in world energy production (through combustion of fossil fuels and biomass) and in world food production (through animal husbandry, irrigated agriculture and forest clearance) have cause heat-trapping "greenhouse gases" (GHGs) to accumulate in the troposphere. This, say climatologists, will change the world's climate, most probably at a much greater rate than has ever been experienced by human societies since the advent- approximately 10000 years ago- of agriculture and settle living (Ando, et al., 1996).

An overwhelming body of scientific evidence now clearly indicates that climate change is a serious and urgent issue. The Earth's climate is rapidly changing, mainly as a result of increases in greenhouse gases caused by human activities and the natural events. Most climate models show that a doubling of pre-industrial levels of greenhouse gases is very likely to commit the Earth to a rise of between 2 – 5°C in global mean temperatures. This level of greenhouse gases will probably be reached between 2030 and 2060. A warming of 5°C on a global scale would be far outside the experience of human civilization and comparable to the difference between temperatures during the last ice age and today. Several new studies suggest up to a 20% chance that warming could be greater than 5°C (Stern Review, 2006). If annual greenhouse gas emissions remained at the current level, concentrations would be more than treble pre-industrial levels by 2100, committing the world to 3 – 10°C warming, based on the latest climate projections (Stern Review, 2006).

Human-induced climate change is caused by the emissions of carbon dioxide and other greenhouse gases (GHGs) that have accumulated in the atmosphere mainly over the past 100 years. The scientific evidence that climate change is a serious and urgent issue is now compelling (Stern Review, 2006). Human activities are releasing greenhouse gases into the atmosphere. Carbon dioxide is produced when fossil fuels are used to generate energy and when forests are cut down and burned. Methane and nitrous oxide are emitted from agricultural activities, change in land use, and other source. CFCs and other gases are released by industrial processes, while ozone in the lower atmosphere is generated indirectly by automobile exhaust fumes.

However, rising levels of greenhouse gases are expected to cause climate change. By absorbing infrared radiation, these gases control the flow of natural energy through the climate system. The climate must somehow adjust to the "thickening blanket" of greenhouse gases in order to maintain the balance between energy arriving from the sun and energy escaping back into space. The projection of climate model is that the global temperature will rise by about 1-3.5°C by the year 2100. This projected change is larger than any climate change experienced over the last 10,000 years. It is based on current emissions trends and assumes that no efforts are made to limit greenhouse gas emissions.

1.1. History of Climate Change

The history of the scientific discovery of climate change began in the early 19th century when ice-ages and other natural changes in paleoclimate were first suspected and the natural greenhouse effect first identified. In the late 19th century, scientists first argued that human emissions of greenhouse gases could change the climate, but the calculations were disputed. Many other theories of climate change were advanced, involving forces from volcanism to solar variation. In the 1960s, the warming effect of carbon dioxide gas became increasingly convincing, although some scientists also pointed out that human activities, in the form of atmospheric aerosols (e.g., "pollution"), could have cooling effects as well. During the 1970s, scientific opinion increasingly favored the warming viewpoint. By the 1990s, as a result of improving fidelity of computer models and observational work confirming the Milankovitch theory of the ice ages, a consensus position formed: greenhouse gases were deeply involved in most climate changes, and human emissions were bringing serious global warming. Since the 1990s, scientific research on climate change has included multiple disciplines and has expanded, significantly increasing our understanding of causal relations, links with historic data and ability to numerically model climate change.

Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. The majority of greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere. In other words, the human activities are releasing greenhouse gases into the atmosphere. Carbon dioxide is produced when fossil fuels are used to generate energy and when forests are cut down and burned. The same thing with Methane and nitrous oxide are emitted from agricultural activities, which play a key role in developing the country, change in land use, and other sources.

1.2. Global Climate System

Because of the heat-trapping properties of the so-called greenhouse gases (GHGs), the average surface air temperature is approximately 15^0C, which is about 33^0C higher than it would otherwise be. In other words, in the absence of this “greenhouse effect” most of Earth’s surface would be frozen, at a mean air temperature of -18^0C (WHO, 1996).

The energy that is not reflected back to space is absorbed by the Earth’s surface and atmosphere. This amount is approximately 240 Watts per square metre (W m–2). To balance the incoming energy, the Earth itself must radiate, on average, the same amount of energy back to space. The Earth does this by emitting outgoing longwave radiation. Everything on Earth emits longwave radiation continuously. That is the heat energy one feels radiating out from a fire; the warmer an object, the more heat energy it radiates. To emit 240W m–2, a surface would have to have a temperature of around –19°C. This is much colder than the conditions that actually exist at the Earth’s surface (the global mean surface temperature is about 14°C). Instead, the necessary –19°C is found at an altitude about 5 km above the surface.

The reason the Earth’s surface is this warm is the presence of greenhouse gases, which act as a partial blanket for the longwave radiation coming from the surface. This blanketing is known as the natural greenhouse effect. The most important greenhouse gases are water vapour and carbon dioxide. The two most abundant constituents of the atmosphere – nitrogen and oxygen – have no such effect. Clouds, on the other hand, do exert a blanketing effect similar to that of the greenhouse gases; however, this effect is offset by their reflectivity, such that on average, clouds tend to have a cooling effect on climate (although locally one can feel the warming effect: cloudy nights tend to remain warmer than clear nights because the clouds radiate longwave energy back down to the surface). Human activities intensify the blanketing effect through the release of greenhouse gases. For instance, the amount of carbon dioxide in the atmosphere has increased by about 35% in the industrial era, and this increase is known to be due to human activities, primarily the combustion of fossil fuels and removal of forests. Thus, humankind has dramatically altered the chemical composition of the global atmosphere with substantial implications for climate.

Because the Earth is a sphere, more solar energy arrives for a given surface area in the tropics than at higher latitudes, where sunlight strikes the atmosphere at a lower angle. Energy is transported from the equatorial areas to higher latitudes via atmospheric and oceanic circulations, including storm systems. Energy is also required to evaporate water from the sea or land surface, and this energy, called latent heat, is released when water vapour condenses in clouds. (Atmospheric circulation is primarily driven by the release of this latent heat. Atmospheric circulation in turn drives much of the ocean circulation through the action of winds on the surface waters of the ocean, and through changes in the ocean's surface temperature and salinity through precipitation and evaporation.

Due to the rotation of the Earth, the atmospheric circulation patterns tend to be more east-west than north-south. Embedded in the mid-latitude westerly winds are large-scale weather systems that act to transport heat toward the poles. These weather systems are the familiar migrating low- and high-pressure systems and their associated cold and warm fronts. Because of land-ocean temperature contrasts and obstacles such as mountain ranges and ice sheets, the circulation system's planetary-scale atmospheric waves tend to be geographically anchored by continents and mountains although their amplitude can change with time. Because of the wave patterns, a particularly cold winter over North America may be associated with a particularly warm winter elsewhere in the hemisphere. Changes in various aspects of the climate system, such as the size of ice sheets, the type and distribution of vegetation or the temperature of the atmosphere or ocean will influence the large-scale circulation features of the atmosphere and oceans.

There are many feedback mechanisms in the climate system that can either amplify ('positive feedback') or diminish ('negative feedback') the effects of a change in climate forcing. For example, as rising concentrations of greenhouse gases warm Earth's climate, snow and ice begin to melt. This melting reveals darker land and water surfaces that were beneath the snow and ice, and these darker surfaces absorb more of the Sun's heat, causing more warming, which causes more melting, and so on, in a self-reinforcing cycle. This feedback loop, known as the 'ice-albedo feedback', amplifies the initial warming caused by rising levels of greenhouse gases. Detecting, understanding and accurately quantifying climate feedbacks have been the focus of a great deal of research by scientists unraveling the complexities of Earth's climate.

1.3. Climate

Climate is defined most simply as the average meteorological conditions experienced in a particular locale, over a specific time period, such as thirty years. Detailed meteorological descriptions include statistic mean values and variance of temperature, precipitation, atmospheric pressure, winds, solar radiation and cloud formation (WHO, 1996).

A region's climate is generated by the **climate system**, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere. The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation. The most commonly used classification scheme was originally developed by Wladimir Köppen. The Thornthwaite system, in use since 1948, incorporates evapotranspiration along with temperature and precipitation information and is used in studying animal species diversity and potential effects of climate changes. The Bergeron and Spatial Synoptic Classification systems focus on the origin of air masses that define the climate of a region.

Paleoclimatology is the study of ancient climates. Since direct observations of climate are not available before the 19th century, paleoclimates are inferred from proxy variables that include non-biotic evidence such as sediments found in lake beds and ice cores, and biotic evidence such as tree rings and coral. Climate models are mathematical models of past, present and future climates. Climate change may occur over long and short timescales from a variety of factors.

Box 1: Definition

Climate (from Ancient Greek*klima*, meaning *inclination*) is commonly defined as the weather averaged over a long period. The standard averaging period is 30 years, but other periods may be used depending on the purpose. Climate also includes statistics other than the average, such as the magnitudes of day-to-day or year-to-year variations. The Intergovernmental Panel on Climate Change (IPCC) glossary definition is as follows:

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Historically, the climate has always dictated the way people live: housing, clothing, diet, agricultural practices, and some even believe that people's temperament is determined by the climate. In turn, the climate is regulated by many factors: the radiation and angle of the sun, the rotation of the earth, the geographical coordinates, the chemical composition of air masses, the proximity and size of the oceans, the regional topography etc. In particular, these factors control air temperature and the amount and distribution of rainfall, which are the two most important aspects of the climate for a particular region. Changes in these factors will certainly lead to a change in global climate. This will subsequently cause an impact on the way we live (Tin , et al., 2004).

Throughout history, the Earth’s climate has undergone different types of changes. In most cases, these changes have been in response to naturally occurring events. However, in the second half of the 20th Century new types of changes became evident that were not part of the natural cycle of climatic variation and were instead a consequence of human activity. The scientific evidence clearly demonstrates that these changes, characterized by rapid increases in average temperature, are likely to continue. The scientific evidence clearly demonstrates that these changes – that are termed as ‘climate change’ – characterized by rapid increases in average temperature, are likely to continue.
Box 2: Climate change and climate variability.

Climate change – A change in climate that persists for decades or longer, arising from human activity that alters the composition of the atmosphere (i.e. greenhouse gas emissions). Climate change is not the same as changes in the weather – these may be more localised, and more short-term.
Climate variability – Natural variations in the climate that are not caused by greenhouse gas emissions (e.g., variability in rainfall and temperature patterns from year to year).
Source: (UNDP, 2011, p. 14)

1.4. Understanding Climate Change in Cambodia

Cambodia faces many challenges in managing its resources sustainably while ensuring secure and productive livelihoods for its population. Climate change is one of the main issues to be concerned in the 21st century.

There are two main seasons of the tropical monsoon climate in Cambodia. The monsoon occurs from May to October, with heavy rains, high humidity and strong winds. From November to April is the dry season, with little rain, low humidity and not much wind. Total rainfall is higher in the coastal zone, with certain areas receiving up to 5000 mm annually, compared to approximately 1400 mm per year in the central plains (MoE, 2002; Daze, et al., 2010). Temperatures are fairly consistent across the country, at an average of 25 to 27° Celsius throughout most of the year. This rises to 26 to 30°C in the hottest months, just before the rainy season. Cambodia’s climate is influenced by the El Niño Southern Oscillation, which causes inter-annual variations, bringing warmer, drier winters in El Niño years and cooler than average summers in La Niña years (McSweeney, C., New, M. & Lizcano, G., undated; Daze, et al., 2010).

Temperature data since 1960 shows an increase in Cambodia’s mean annual temperature, which has been increasing by approximately 0.18°C per decade. There are some variations in the rate of temperature change at different points of the year. In the drier seasons, temperatures have increased by about 0.20-0.23°C per decade, while in the rainy season the rate of change was approximately 0.13-0.16°C. There has also been an increase in the number of hot days and hot nights, with 12.6% more hot days and 17.2% more hot nights. The number of cold days and cold nights has decreased by 5.2% and 12.6%, respectively. Future projections suggest that these trends will continue, with the average annual temperature rising by 0.7-2.7°C by the 2060s and 1.4-4.3°C by the 2090s throughout the year (depending on the greenhouse gas emission scenario and the climate model used), an increase in the number of hot days and nights and a decrease in the number of cold days and nights (McSweeney *et al*., undated; Daze, et al., 2010). The rate of temperature change is expected to be higher in the lower altitude areas of the country, including the central plains, and lower in the mountainous regions (MoE, MEF & UNDP, 2011; Daze, et al., 2010).

While the available precipitation data do not show significant changes in average rainfall since 1960, climate models predict an increase in annual rainfall in the coming decades. Again, there are seasonal variations in the projections. By the 2090s, rainfall during the rainy season is anticipated to increase by up to 31% in the June-August period and by up to 42% in September-November. During December-February, however, rainfall is projected to decrease by up to 54%. This decrease offsets the increases during the other seasons when looking at mean annual rainfall. There is also a projected increase of up to 14% in the proportion of total rainfall that falls in heavy rainfall events, as well as increases in maximum one- and five- day rainfalls (up to 54 mm for one-day and 84 mm for five-day). In practical terms, this translates to later, shorter and wetter rainy seasons and longer, drier dry seasons (McSweeney *et al*., undated; Daze, et al., 2010). It may also mean anomalies in seasonal patterns, such as the occurrence of short droughts during the rainy season, which has been observed in recent years. Collectively, these impacts mean increased uncertainty in the availability of water for domestic and productive purposes.

Based on the Intergovernmental Panel on Climate Change (IPCC) projections for the rate of sea level rise, it is estimated that up to 25 000 hectares (ha) of Cambodia's coastal zone may be permanently inundated with sea water by 2100, with an even larger area affected by salinization. However, given the complexity of projecting sea level rise, this may be a low estimate (MoE, MEF & UNDP, 2011; Daze, et al., 2010).

A summary of the available scientific information on climate change impacts in Cambodia. It is important to note that modeling climate impacts is complex and difficult to do with any precision, and that more data and research are needed to get a clearer picture of how climate change will manifest in Cambodia, particularly at the local scale. However, what is clear is that the climate in Cambodia will be increasingly variable and that the impacts of climate change will be evident primarily through extremes in the water resource sector, which have significant implications for other sectors (Johnston et al., 2010; Daze, et al., 2010).

2. Cause of Climate Change

If the people both developed and developing nations have not done something to reduce emissions, current climate models predict a global warming of about 2^0C between 1990 and 2100 (Acosta, et al., 1997). This will be the effects of aerosol and the delaying effect of the oceans. The Earth's surface and lower atmosphere would continue to warm by further 1-2^0C even if greenhouse gas concentrations stopped rising in 2100. Additionally, the Earth's average sea level is predicted to rise by about 50 cm by 2100 (Acosta, et al., 1997). It means the uncertainty range is large-15 to 95 cm- and changing oceans currents could cause local and regional sea level rise much more or much less than the global average. The main cause of this rise is the thermal expansion of the upper layers of the ocean as they warm, with some contribution from melting glaciers.

On the other hand, the Earth's climate is already adjusting to past greenhouse gas emission. The climate system must adjust to changing greenhouse gas concentrations in order to keep the global energy budget balanced. This means that the climate is changing and will continue as long as greenhouse gas levels keep rising. In reality, how the large the change is likely to be relative to the natural climate fluctuations that humans societies and natural ecosystem have learned to adapt to.

More importantly, human activities emit greenhouse gases (GHGs). Emission started to rise dramatically in the 1800s due to the Industrial Revolutions and change in land use. Many greenhouse-gas-emitting activities are now essential to the global economy and a fundamental part of modern life. At the same time, humans are increasingly influencing the climate and the earth's temperature by burning fossil fuels, cutting down forest and farming livestock, so this will add enormous amounts of greenhouse gases to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming. Carbon dioxide from the burning of fossil fuels in the largest single source of greenhouse gas emission from human activities; therefore, the supply and use of fossil fuels accounts for about three-quarters of mankind's carbon dioxide (CO_2) emission (equal to some 5.9 billion metric tonnes of Carbon in 1992), one-fifth of the methane (CH4), and a significant quantity of nitrous oxide (N2O). It also produce nitrogen oxides (NOx), hydrocarbons (HCs), and carbon monoxide (CO), which, though not greenhouse gases themselves, influence chemical cycles in the atmosphere that create or destroy other greenhouse gases, such as tropospheric ozone (Acosta, et al., 1997).

Another cause of climate change is that some gases in the Earth's atmosphere act a bit like the glass in a greenhouse, trapping the sun's heat and stopping it from leaking back into space. Many of these gases occur naturally, but human activity is increasing the concentrations of some of them in the atmosphere, such as: carbon dioxide (CO2), methane, nitrous oxide, and fluorinated gases. According to the extraction from the European Commission's website in 2015, **CO_2** is the greenhouse gas most commonly produced by human activities and it is responsible for 64% of man-made global warming. Its concentration in the atmosphere is currently 40% higher than it was when industrialization began.

Other greenhouse gases are released in smaller quantities, but they trap heat far more effectively than CO_2, and in some cases are thousands of times stronger. Methane is responsible for 17% of man-made global warming, nitrous oxide for 6% (European Commission, 2015). According to European Commission 2015, causes for rising emissions include:

- **Burning coal, oil and gas** produces carbon dioxide and nitrous oxide.
- **Cutting down forests (deforestation).** Trees help to regulate the climate by absorbing CO_2 from the atmosphere. So when they are cut down, that beneficial effect is lost and the carbon stored in the trees is released into the atmosphere, adding to the greenhouse effect.
- **Increasing livestock farming.** Cows and sheep produce large amounts of methane when they digest their food.
- **Fertilizers containing nitrogen** produce nitrous oxide emissions.
- **Fluorinated gases** produce a very strong warming effect, up to 23 000 times greater than CO_2.

With regard to global warming, the current global average temperature is 0.85ºC higher than it was in the late 19th century. Each of the past three decades has been warmer than any preceding decade since records began in 1850 (European Commission, 2015). The world's leading climate scientists think human activities are almost certainly the main cause of the warming observed since the middle of the

20th century. An increase of 2°C compared to the temperature in pre-industrial times is seen by scientists as the threshold beyond which there is a much higher risk that dangerous and possibly catastrophic changes in the global environment will occur. For this reason, the international community has recognized the need to keep warming below 2°C (European Commission, 2015).

3. Effect and Impact of Climate Change

Climate change consists of three key effects: changes in regional rainfall patterns, sea level rise, and increased average temperature. Meanwhile, climate change is having serious impacts on agricultural production, water resources, human health, coastal areas, forest and ecosystems. Increasing floods, droughts, windstorms and other climate change related disasters, both in frequency and intensity, have caused enormous damages to many countries throughout the world.

3.1. Effect of Climate Change by Sectors

It covers a wide range of potential impacts of climate change. It addresses the implications of global warming, sea-level rise, changed precipitation and evaporation and stratospheric ozone depletion for human settlement, which includes housing and infrastructure, and for the energy, transport and industrial sectors. It also covers the likely impacts of global warming and stratospheric ozone depletion on human health and air quality, and the potential overall impact on human health and natural systems of increased levels of ultraviolet-B (UV-B) radiation reaching the earth's surface as a result of depletion of the stratospheric ozone layer.

3.1.1. Human Health

Global warming is expected to lead to more cardiovascular, respiratory, and other disease. Injuries, psychological disorders, and deaths would results from a greater intensity and duration of heat waves and perhaps of floods, storms, and other extremes climate events. While warmer temperatures in colder climates should reduce cold-related deaths such as positive effectives are not likely to offset the negative ones (Acosta, et al., 1997). Climate change impact both direct and indirect impact. The direct impacts of climate change on health include an increase in heat stress and in cardiovascular, respiratory, allergic and air borne diseases. Increase in frequency and/or intensity of extreme weather events could result in death, injuries, psychological disorders, and damage to public health infrastructures (Tin , et al., 2004).

3.1.2. Water Resource

Climate change is expected to result in modified weather patterns in the Lower Mekong Basin (LMB), in terms of both temperature, rainfall and wind and also the intensity, duration and frequency of extreme events, affecting ecosystems, agriculture and food production and livelihoods. Typical livelihoods in the LMB are reliant on natural resources and therefore likely to be adversely affected by the impacts of these shifts. Current predictions of how the climate is likely to have changed in the LMB by 2030 indicate mean temperature rise of 0.79°C, precipitation increase (mainly in the wet season) of 20 cm (13.5 percent), and Basin runoff rising by up to 21 percent (107,000 million cubic metres). Increased flooding will likely affect all parts of the LMB, but especially downstream areas

(Eastham et al. 2008; cited in Chem & So, 2012). Cambodia's Tonle Sap Lake is the largest freshwater lake in Southeast Asia. Part of the Mekong system, the Lake's resources directly or indirectly benefit the livelihoods of almost half of Cambodia's population, particularly fishers and farmers. While climate change will likely alter the lake-floodplain system over the next few decades, new hydropower developments could have immediate adverse consequences for local livelihoods and food security. The Lake is particularly vulnerable as climate change will affect the Basin's unique flood pulse system, subsequently altering water regimes (Eastham et al. 2008; cited in Chem & So, 2012). Cambodia has experienced increasingly frequent flooding, drought and windstorms since 1989, such as the 2000 and 2011 floods. Indicative of the changing climate, disasters and climate-related hazards exact huge socio-economic costs on the country. The floods in 2000 and 2011 were perhaps the most devastating in recent history, displacing hundreds of thousands of people, causing hundreds of deaths and other losses. The extensive flooding in 2011 destroyed much of the past 10 year's investment in infrastructure in both rural and urban areas of the Tonle Sap and Mekong Floodplains (Chem & So , 2012).

3.1.3. Agriculture

In 2007, the Inter-Governmental Panel on Climate Change (IPCC) stated that climate change is undeniably occurring as temperature having increasingly risen during the past 25 years. It predicts that global average temperature could rise by as much as 3C^{o} by 2100 (Sim, et al., 2012, p. 1). Moreover, regarding the other impacts of climate change, including global warming is expected to be sea level rise and an increase in climate extreme, such as floods, droughts, and storms. This change will effect to crop production system and negatively affect rice yields. Cambodia's most important crop is rice which is also the country's most valuable export crop. In addition to this, Agri-consulting International (2006); cited in (Sim, et al., 2012, p. 2), estimated that rice is grown on 84% of all cultivated land in Cambodia rice, and it is grown in a variety of system, dependent on differing rainfall and flooding patterns. Furthermore, in 2008, 32.5% of Cambodia's economy was dependent on agriculture (ADB, 2010; cited in Sim, et al., 2012). Nearly 60% of the country's population gained its income from agriculture (Sim, et al., 2012).

3.1.4. Infrastructure

The 2013 monsoon rainy season (May-October 2013) was the large-scale flooding return to South-East Asia after a calmer 2012. The flood combined with successive typhoons, which is a rise in the level of the Mekong River and trans-boundary flash floods in the western province with heavier-than-average monsoon rains caused extensive flooding across Cambodia. It damaged 1.8 million individual living in 20 provinces, killed 168 people, the majority of whom were children (HRF, 2013; MRD, 2014). Within the big challenge of the Cambodia today, the country is to cope with the impacts of climate change on rural and social infrastructures. Yearly, flood and drought damage huge national economy that needed to remedy rural structures such as irrigation, dams, roads, bridges, shelters, and rice field (MRD, 2014).

3.2. Impact of Climate Change

3.2.1. Global Impact

The impacts of climate change do not recognize national boundaries, i.e. both developed and developing countries suffer from them (Tin, 2010). However, Cambodia is highly vulnerable to climate change impact due to the capacity of people is limited, and the poverty make them faced challenges to deal with its impact and resources and to adapt to climate change. For example, rising sea level will threaten millions of people living in island states and in low-lying deltas in countries like Bangladesh, Egypt and China. Most of the endangered areas are in South and South East Asia, where some 30 of the world's largest cities are located (Tin, 2010). In addition, global warming will also affect water supplies and reduce food production in the tropics and sub-tropics (Tin, 2010).

Box 3: Global climate change impact

Some Facts about Climate Change:

- The world is heating up – fast. Temperatures are rising more quickly than they have done for 10,000 years
- The 1990s were the warmest decade on record, and 1998 was the hottest year
- The earth's average surface temperature has warmed between 0.3 and 0.6 degrees Celsius in the last 100 years. It may rise by two degrees in the next 100 years, if we go on producing greenhouse gases at the present rate
- Sea levels have risen by between 10-25 centimetres in the last 100 years, as polar ice caps have melted. They are projected to rise another 50 centimetres by 2100
- There have been unpredictable and extreme weather patterns – freak weather disasters such as hurricanes, storms, and floods.

Source: Just a Lot of Hot Air? The Panos Institute, 2000. London,UK.

Source: CDM, 2010

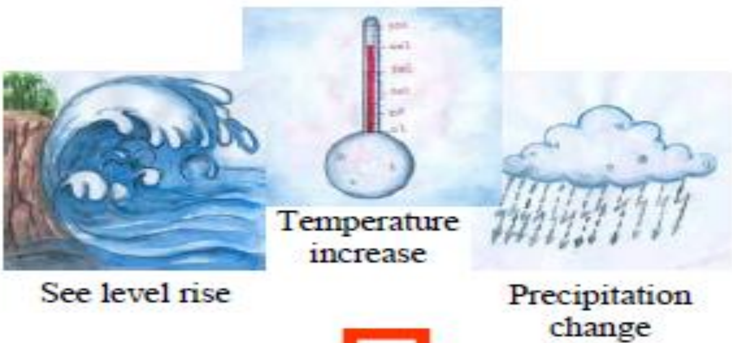

Figure 1: Potential impact of climate change

Climate change is having serious impacts on agricultural production, water resources, human health, coastal areas, forest and ecosystems (Tin, 2010). Increasing floods, droughts, windstorms and other climate change related disasters, both in frequency and intensity, have caused enormous damages to many countries throughout the world.

Water Resources

Water is a critical resource for agriculture and rural development in Cambodia, used for household consumption, agriculture, industry, power generation and tourism, among other purposes (Daze, et al., 2010). Estimates of water use by sector show that 96% of the total water used goes to agriculture, 3% for domestic uses and 1% for industrial purposes (MoWRAM, 2008; Daze, et al., 2010). As the country grows and moves forward on its development pathway, it is anticipated that demand in all of these sectors will increase in the coming years (MoWRAM, 2012; Daze, et al., 2010).

At the same time, water availability is expected to vary due to climate change effect. With increased evapo-transpiration due to rising temperatures, availability of surface water decreases. These effects in turn will lead to uncertainty in availability of water for domestic and productive uses, potentially causing water scarcity and decreasing water quality. In addition, floods may cause damage to rural water infrastructure including water supply and irrigation systems. In other words, these impacts will have the greatest consequences for the poorest people, including small-scale farmers and fishers. There will be increased need for water infrastructure designed to manage fluctuations in water availability (water storage and distribution, etc.). Similarly, coastal zone management strategies will also need to be adapted to the changing circumstances caused by sea level rise and changes to the hydrological system. With an increase in the occurrence of droughts and floods, greater demand will be placed on emergency response systems, and there is potential for resources to be diverted from development initiatives to respond to emergencies as they arise (TKK & SEA, 2009; Eastham *et al*., 2008; Johnston *et al*., 2009; MoE, 2006; MoE, MEF & UNDP, 2011; MRC, 2010; Daze, et al., 2010). Reduced water supplies would put additional pressure on people, agriculture, and the environment. Climate change will probably exacerbate the stresses caused by pollution, population increase and economic growth. The most vulnerable regions are arid and semi-arid areas, low-lying coasts, deltas and small islands.

Agricultural Production

Cambodian agriculture is largely rain-fed, with only approximately 20% of farmland under irrigation (MoWRAM, 2012; Daze, et al., 2010). Drought and flood events in recent years demonstrate the damaging effects these extreme events can have on agricultural production. In 2004-05, a drought affected approximately 30% of the cultivated land in Cambodia, causing a 14% decrease in the national rice yield (Daze, et al., 2010). While there is not a lot of data available for future yield impacts for Cambodia, a World Bank study on the economics of adaptation to climate change in neighbouring Vietnam projected that, with no adaptation, rice yields would decrease by 5.8 to 9.1 million metric tons per year by 2050, depending on the climate scenario used (Daze, et al., 2010). The study also estimated decreases in production for other crops, with maize at 0.3 to 1.9 and vegetables at 0.9 to 1.7 metric million tons annually. These scenarios translated to a reduction in Vietnam's gross domestic product (GDP) of 0.7 to 2.4% by 2050 (World Bank, 2010; Daze, et al., 2010).
In addition to these effects, climate change scenarios for agriculture have difficulty for poor people, who are most vulnerable to variability and extreme events affecting agriculture. The poorest households feel the impacts most acutely in their income, food security and health because they are heavily reliant on agriculture for their incomes; they tend to spend a higher proportion of their incomes on food (World Bank, 2010; Daze, et al., 2010). Due to higher temperature and changes in rainfall patterns will have impacts on crop yields and productivity. Yields will probably decrease due to excessive irrigation demand, increased rainfall, which will cause soil erosion and soil leaching, and crop damages caused by increasing extreme climate events. Sea level rise will also cause losses in cropland in low-lying coastal areas. The most vulnerable groups are the landless, poor, and isolated people of developing countries. These countries normally have weak infrastructure, limited access to technology and information, and some also experience armed conflict.

Human Health

Generally, good health is both a determinant and an outcome of resilience. The direct impacts of climate change on health include an increase in heat stress and in cardiovascular, respiratory, allergic and air borne diseases. Increase in frequency and/or intensity of extreme weather events could result in death, injuries, psychological disorders, and damage to public health infrastructures. Tropical diseases such as malaria and dengue fever are also likely to increase as the habitats for mosquitoes and other vectors (insects) expand when the temperature rises. Food- and water-related diseases will also increase due to warmer temperatures, reduced water supplies and proliferating microorganisms. The poor will be more vulnerable to the health impacts than the rich. However, richer countries will also be increasingly vulnerable as their populations' age. Further, the rate of evapo-transpiration increases can negatively impact availability of safe water. Changing rainfall patterns and sea level rise also affect water quality and quantity. With reduced access to safe sources of water for domestic use, people are more at risk of water- and food-borne diseases, including diarrhea and cholera (Daze, et al., 2010).

Coastal Areas

By observation, the global average sea level has risen by 10 to 25 cm over the last century, which is mainly related to an increase of 0.3-0.6oC in the global average air temperature since 1860 (Tin, 2010). As the current trend in global warming continues to occur from year-to-year, sea level is predicted to rise another 15 to 95 cm by the year 2100. This will occur due to the thermal expansion of ocean water and an influx of freshwater from melting glaciers and ice in the future. The low-lying coastal zones and small islands are extremely vulnerable to sea level rise. It is projected that a 1 m sea-level rise would cause estimated land losses of 6% in the Netherlands, 17.5% in Bangladesh and over 50% for some small island states. For Cambodia, it was found that 56% of the Koh Kong town area would be inundated when there is a 1 meter sea level rise; if the sea level rises by 1m, the total area that will be under the sea water permanently would be about 44 km2 (MoE, 2001).

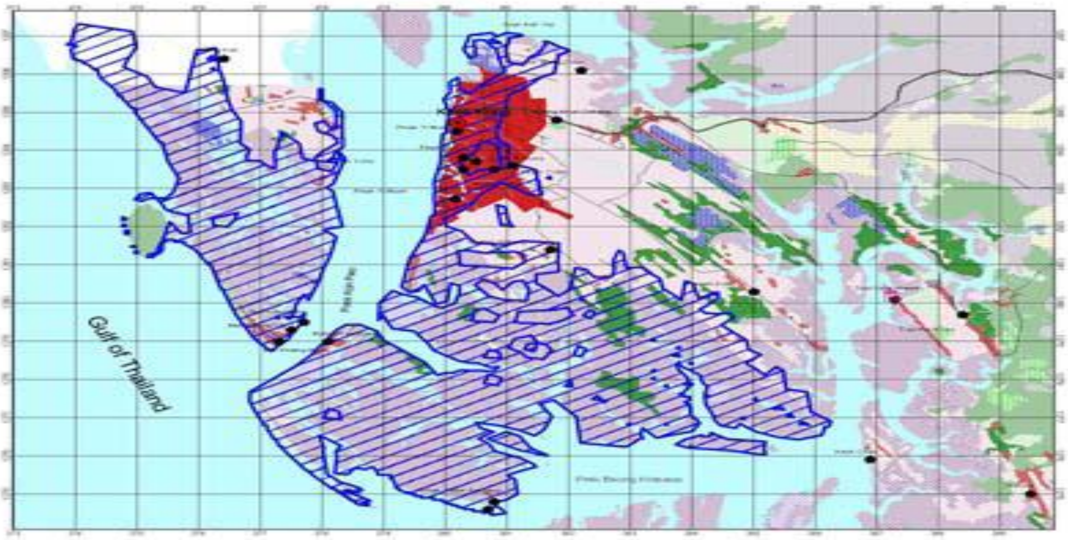

Figure 2: Potential impacts of 1 m sea level rise in Koh Kong province, source: MoE, 2001

Forest and Ecosystems

Forests play an important role in the climate system. They are a major reservoir of carbon. They also directly affect local, regional, and continental climate by influencing ground temperature, evapotranspiration, heat reflectivity, cloud formation, and precipitation. Cambodia's forests will also be affected by climate change impacts. The predicted increase in temperature has the potential to change the extent and composition of forests, including a decrease in wet forests and an increase in moist forests, each of which currently account for approximately 20% of the country's forests (Cambodia National Mekong Committee, 2010; Daze, et al., 2010). Changes to forest composition may lead to changing availability of forest resources for rural livelihoods. These effects will lead to the degradation and/or loss of forests, leading to decreased income security for forest-dependent communities. The community-based natural resource management plays also a key role in helping the people who lived in the forest. With increasing degradation and loss of forests, this important coping mechanism will no longer be available. As well, there is potential for increased competition for forest resources, and the possibility of conflict between different forest users.

3.2.2. Regional Impact

Poverty and high population densities in most South East Asian countries would mean the even small changes in land or crop productivity would have serious social and economic consequences (Tin, 2010). Also, the impact caused by the additional heat stress, shifting monsoon, increasing temperature, changing rainfall patterns, and drier soil may decrease agricultural yields in regional countries.
The most importantly, the threat to livelihood probably comes from coastal flooding because of sea level rise. In other word, most productivity lands in the region, such as the Mekong and Chao Phraya river deltas, and the Central Plain surroundings Tonle Sap Great Lake in Cambodia. Among the countries in South East Asia, Cambodia is one of the poor, which have limited resource to adapt to climate change, especially for those who living in the rural Cambodia. The impact of climate change such as reduced water resource, degraded soils and impoverished forest and fishing grounds may thus result in the destruction of people's livelihood (Tin, 2010).

3.2.3. Impact on Cambodia

As a poor agrarian country, Cambodia is really vulnerable to the climate change impact. According to the study from the past five year show more than 70% of rice production loss was principally due to flooding while drought was 20% of the losses (Tin, 2010).
Table 1: Type of impact of climate change on Cambodia

No	Type of Impacts	Situation	Remarks
1	Rainfall	increased by 3%-35% from current condition	Increase by 2100
2	Temperature	Increased by 1.3 C^0 -2.5 C^0	Increased occurrence of extreme weather
3	Sea level rise	Increase of 1 meter would inundate many coastal area of Cambodia	• A total area of Koh Kong approximately 44 km^2 would be permanently underwater. • mangrove ecosystem to be submerged • 56% of the settlement area would be flooded

Source: (CDM, 2010)
On the other hand, Cambodia is prone to natural hazards, namely droughts, floods and storms, which cause economic losses and damage livelihoods (Nang, et al., 2014). Typhoon Ketsana in 2009, for instance, led to agricultural losses of USD132 million and caused damage and destruction in 14 of Cambodia's 24 provinces; further, most of the affected districts are the poorest in the country (Ros et al. 2011, cited in Nang, et al., 2014). To respond to natural hazards, the Government primarily provides in the form of emergency relief, including temporary shelters and some livelihood restoration such agricultural inputs or subsidies towards their cost. Also, flood and drought are the most common

natural disasters and results in loss of lives, crop failures, and destruction of property and infrastructure (MoE, 2006; cited in Heng, et al., 2012). The following table summarizes the Cambodia natural disaster from 1991-2011.

Table 2: A summary of the impacts of extreme weather events (floods, droughts and typhoons) in Cambodia from 1991–2013

Year	Events (month/s)	No. of Province affected	Impacts
1991	Flood (August)	10	• 100 people died, 900,000 people affected • 243,000 hectares agricultural land affected. $150,000,000US estimated damages.
1994	Drought (June)		• 5,000,000 people affected $100,000,000 US estimated damages.
	Flood (July)	6	• 506 people killed, 12,000 people displaced.
1996	Flood (September)	10	• 59 people killed, 1,372,410 people affected • 30,577 hectares hectares agricultural land affected, 584,693 people affected by food shortage • $1,500,000US estimated damages
1997	Typhoon (November)	1	• 23 people kill, 200 people missing
1997-1998	Drought(“Late 1997-Early 1998”)		• Food shortages mid-year
1999	Flood (July-August)	7	• 4 people killed, 535,904 people affected, 8100 people displaced, 7000 homes affected • 17,732 hectares agricultural land affected, $500,000US estimated damages
	Flood (November)	6	• 25,847 families affected, 3561 homes affected • 9990 hectares agricultural land affected
2000	Flood (July-November)	22	• 347 people killed (80% children.), 3,448,629 people affected, 387,000 people displaced • 325,043 homes affected • 421,569 hectares agricultural land affected • $156,655,500US estimated damages
2001	Drought (“Most of the year”)	12	• 530,844 people affected by food shortages
	Flood (August-October)	18	• 62 people died (70% children), 2,121,952 people affected, 508,666 people displaced • 201,371 hectares agricultural land affected, 945,665 people affected by food shortages • $16,900,000US estimated damages, (total 2001 drought & flood: $36,000,000US) • Increase in diarrhoeal disease
2002	Drought (January-August)	24	• 2,660,000 people affected, 30,000 forced migration • 246,643 hectares agricultural land affected, 1,000,000 people affected by food shortages

			• $38,000,000US estimated damages
	Flood (August)	6	• 29 people killed, 1,470,000 people affected, 450,000 people displaced • 2731 hectares agricultural land affected, 470,000 people affected by food shortages • $100,000US estimated damages
2004-2005	Drought (October2004-April 2005)	14	• 2,000,000 people affected, 1,000,000 people affected by food shortages • 520,000 hectares agricultural land affected, $21,000,000US estimated damages
2006	Tropical Storm Prapiroon, Flood (August-September)	9	• 13 people killed, 33,000 people displaced, 263 houses affected • 17,515 hectares agricultural land affected

Table 2: A summary of the impacts of extreme weather events (floods, droughts and typhoons) in Cambodia from 1991–2013 (cont')

Year	Events (month/s)	No. of province affected	Impacts
2007	Flood (June)	1	
	Tropical Storm Pabuk, Flood (August)	8	• 5 people killed, 160,000 people affected • 8000 hectares agricultural land affected • $1,000,000US estimated damages
2008	Flood (August)	1	
	Drought (September)	1	
2009	Drought (August)	7	• 79,000 hectares agricultural land affected
	Typhoon Ketsana, flood (September-October)	14	• 43 people killed, 67 people injured, 180,000 people affected, 6210 families displaced • 10,000 homes affected • 57,000 hectares agricultural land affected, 48,000 families affected by food shortages • $131,996,415US estimated damages • Increase diarrhoeal disease
	Typhoon Mirinae (November)	1	• 2 people killed, 4 people injured
2009-2010	Drought (November-2009-July2010)		
	Flood (October-November)	8	• 8 people killed, 5 people injured,9726 families affected • 33,096 houses affected • 18,527 hectares agricultural land affected • $70,000,000US estimated damages
2011	Flood (August-November)	18	• 247 people killed, 23 people injured,1,640,023 people affected, 214,000 people displaced, 270,371 houses affected

			• 423,449 hectares agricultural land affected, 15% households severely food insecure • $521,000,000 estimated damages • Increase in diarrhoeal disease
2012	Tropical Storm Pakhar (March-April)	1	• 5 people injured • 145 houses affected
	Drought (July-August)	14	• 146,140 hectares agricultural land affected
	Flood (September-October)	8	• 27 people killed, 14,322 families affected, 4057 families displaced • 12,274 houses affected, 16,510 hectares agricultural land affected
	Tropical Storm Gaemi (October)	7	
2013	Flood (August)	4	• 13 people killed, 2592 families affected, 450 families displaced, 230 houses affected • 20,000 hectares agricultural land affected
	Flood, Typhoon Usagi, Tropical Storm Krosa (September-October)	21	• 188 people killed, 29 people injured, 1,735,828 people affected, 144,044 people displaced • 240,195 houses affected • 384,846 hectares agricultural land affected • $1,000,000,000US estimated damages • Increase in diarrhoeal disease

Source: (Davies, et al., 2014)

The flood occurred in 2000 has also acutely ruined almost entire crop yields (82% of households lost their yields in 2000; 66%, 2001; and 41%, 2002). After that, from 2004-2009, the flood decreased steadily, yet the drought has become the concern of people causing the yields reduce (38% in 2005&2007; 92%, 2009). When drought happens, 67% of people changed types of rice, 84% farmed normally, 10% used additional fertilizers, 16% conducts rituals asking for rain, 97% uses lesser water, 12% buys water, and 94% uses water from different sources (Huoy, 2011).

4. Conclusion

Climate change and global warming are considered as the vulnerable to both developed and developing countries throughout the world. Meanwhile, the causes of climate change from the effects of aerosol and the delaying effect of the oceans. The Earth's surface and lower atmosphere would continue to warm by further 1-2^{0}C even if greenhouse gas concentrations stopped rising in 2100. The climate is changing and will continue as long as greenhouse gas levels keep rising. Human activities emit greenhouse gases (GHGs). Humans are increasingly influencing the climate and the earth's temperature by burning fossil fuels, cutting down forest and farming livestock. On the other hand, the effect and impact of climate change will focus on the key sectors, including: water resource, human health, agricultural production, coastal zone, infrastructure, and forestry and ecosystem. Cambodia is a poor agrarian country, is really vulnerable to the climate change impact. As indicated, the study over the past five year show more than 70% of rice production loss was principally due to flooding while drought was 20% of the losses. The type of impact of climate change on Cambodia is included rainfall, temperature, and sea level rise.

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ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia

MODULE II:

CLIMATE CHANGE ADAPTATION

December, 2021

Introduction to the Training Manual

Background and Aims of Training: Climate change is one of the biggest long-term risks to global development. This makes choices and investment made in climate change mitigation vital for ensuring sustainable and inclusive growth. Adaptation and Mitigation is the most comprehensive and up-to-date scientific, technical and economic assessment of options to mitigate climate change. This training manual supported a 4-day training on **"Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia"**. The development of a training manual and the training of trainer program on climate change adaptation and mitigation that are the critical to achieving the objectives of the training in building capacity to adapt to climate change and climate variability in Cambodia.

Purpose of this Training Manual: This training manual seeks to provide knowledge of and training in Climate Change Adaptation and Mitigation. In this context the trainee will learn the definition of adaptation, mitigation, important of climate change adaptation, vulnerability and adaptation assessment, climate change adaptation action like NAPA, concept of NAPA, NAPA implementation, NAP. This training manual also provide the definition and scope of mitigation, greenhouse gas definition, linkage between mitigation and adaptation, cost effective mitigation, mitigation opportunity and potential by sector, land use, land use change and forestry and other activities and program the help people to mitigate with climate change as well as.

How the training materiel was developed: There are many sources for developing this manual. Internet is the major source including www.who.org and www.oaresciences.org which is the international Journals for best matching literature review. However, since the scope of this manual is mainly demonstrate in the context of Cambodia; it is very important to access the documents from IPCC, MoE and other reports for documentation and also others research as well.

How to use this manual: This manual can be used for additional documentation for raising-up general knowledge in climate change adaptation and mitigation. It does really benefit for those who want to know about adaptation and mitigation to climate change and other researches. Before reading this manual please doesn't forget to go through with this Introduction.

Module II: Climate Change Adaptation and Mitigation

The purpose of this training module is to provide trainees in national and sub-national of governmental institutions with KSA (Knowledge, Skills, and Attitude) on climate change adaptation and gender concept.

Target Group:

Lecturers, researchers, and staffs in agricultural universities/institutions in Cambodia who interest on climate change.

Learning Outcome:

At the end of the module, the participants will be able to:

1. Understand the climate change adaptation option
2. Understand how do the vulnerability assessment
3. Understand the impact of climate change on gender with adaptation

Learning Objectives:

1. To provide knowledge on climate change adaptation option.
2. To provide the trainees to understand how to do the vulnerability assessment
3. To provide the trainees to understand the impact of climate change on gender with adaptation

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ABBREVIATIONS

ADB	Asian Development Bank
AEZ	Agro-ecological zones
ASEAN	Association of Southeast Asian Nations
CC	Climate Change
CCA	Climate Change Adaptation
CCCA	Cambodia Climate Change Alliance
CCCO	Cambodian Climate Change Office
CCCSP	Cambodia Climate Change Strategic Plan
CCM	Climate Change Mitigation
EPA	United States Environmental Protection Agency
GEF	Global Environment Facility
IPCC	Intergovernmental Panel for Climate Change
LDCEG	Least Developed Countries Expert Group
MAFF	Ministry of Agriculture, Forestry and Fisheries
MOE	Ministry of Environment
MRC	Mekong River Commission
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action to Climate Change
NCDM	National Committee for Disaster Management
RGC	Royal Government of Cambodia
SRES	Special Report on Emissions Scenarios
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USGCP	United States Global Change Research Program
WB	World Bank
WFP	United Nations World Food Programme

CLIMTE CHANGE ADAPTATION

1.1. Introduction to Climate Change Adaptation

Mitigation of climate change has been the focus of considerable research and policy activity. However, it cannot address the impacts of past and current greenhouse gas emissions. Adaptation plays an important role, in this context as well as to deal with the present and future impacts of climate change (Koh & Lovleen, 2010).

The Third Assessment Report of the Intergovernmental Panel for Climate Change (IPCC) has demonstrated the importance and complexity of adaptation (Barry & Olga, 2001).

Climate change is a transnational issue but adaptation measures are usually developed at the regional, national and local levels. This trend is being more frequently witnessed in developing countries, including members of the Association of Southeast Asian Nations (ASEAN), which are most vulnerable to the impacts of climate change (Koh & Lovleen, 2010).

Study on climate change has long focused on mitigation. But regardless of how much mitigation is achieved or will be achieved, the climate is already changing, and significant (Koh & Lovleen, 2010) is expected in the coming decades due to past emissions of greenhouse gases. Therefore, adaptation has drawn more and more attention in recent years, and it is recognized that serious effort has to be made on this front in order to reduce our vulnerability to the changing environment. On the other hand, the fact that human society can, and does, adapt to climatic changes has implications for understanding the true impact of climate change and for designing optimal climate change strategies given uncertainty. On the other hand, given that some climate change is already inevitable, it is necessary to think about and act on adaptation now (smith et al., 2010).

Adapting to climate change is one of the most challenging problems facing humanity. The time for adaptation action to ongoing and future climate change is now upon us. Living with climate change involves reconsidering our lifestyles and goals for the future, which are linked to our actions as individuals, societies and governments worldwide. Look out the window and assess the weather. If it is hot, change into a lighter shirt. If it is raining, take an umbrella. This is adaptation to changing weather. Adaptation to changing climate is a different matter. The climate may change either slowly or rapidly, and the changes may be irreversible and impossible to predict with any accuracy. The simple principles of adapting to changing weather begin to break down when the climate changes. In the context of climate change the options for adaptation may involve relocating homes, moving cities, changing the foods we grow and consume, seeking compensation for economic damages, and mourning the loss of our favorite place or iconic species.

The difference between adapting to changing weather and adapting to a changing climate lies both in the time-frame and in the significance of the changes required. Moreover, the consequences of not adapting to climate change may be far more serious than not adapting to changing weather.

1.1.1. Definition

1.1.1.1. Adaptation

Adaptation can be classified either as planned adaptation or as autonomous adaptation(Koh & Lovleen , 2010).Base on the Intergovernmental Panel on Climate Change (IPCC) defines climate change adaptation as in the **Box 1**

Box 1. Adaptation Definition define by IPCC

Adaptation ‘’ The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects

Incremental adaptation Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

Transformational adaptation Adaptation that changes the fundamental attributes of a system in response to climate and its effects (IPCC, 2014).

Adaptation: ‘’ Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effect, which moderate harm or exploit beneficial opportunities’’(IPCC, 2001).

Many societies have a long history of coping with variable climate, at several scales, from diurnal to seasonal and annual variations, and over space. However, global climate change is expected to far exceed the range in climate that societies are accustomed to. While the exact nature of the change is difficult to predict with certainty, evidence of wide-ranging changes and impacts is growing, and the area of climate modeling to project future changes is a very active field of research.

Adaptation has been described extensively in the literature, and yet there is no universal agreement on a precise definition. The context clearly matters, and adaptation can be viewed as an adjustment, process or outcome (LDCEG, 2012).

These are probably the most authoritative definition. However, there are other definitions that are also often used.

Box 2. Adaptation Definition define by others

Adaptation ‘’ A process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed and implemented’’ (UNDP, 2005).

Adaptation ‘’A process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides ’’(Burton Ian, 1992; Smit, et al., 2000)

Adaptation ‘’ Adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer term climate change’’ (Smit, 1993; Smit et al., 2000).

Adaptation ‘’ The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change’’(Smit et al., 2000; Stakhiv, 1993).

Adaptation '' Adaptation to climate change includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system''(Smit et al., 2000; Smith et al., 1996).

Adaptation : ''is possible adjustments, spontaneous or planned, of people, plants, ecosystems, etc. to climate change to reduce adverse impacts, to take advantage of opportunities or to cope with the consequences of climate change''(MOE, 2004).

There are two type of adaptation included: Reactive adaptation and Anticipatory Adaption

Table 1 Adaptation measures in key vulnerable sector in developing countries

Vulnerable Sectors	Reactive adaptation	Anticipatory Adaptation
Agriculture and Food security	- Erosion control - Dam construction for irrigation - Changes in fertilizer use and application - Introduction of new crops - Soil fertility maintenance - Changes in planting and harvesting times - Switch to difference cultivars - Education and outreach programmes on conservation and management of soil and water	- Development of tolerant/resistant crops (to drought, salt, insect/pests) - Research and development - Soil-water management - Diversification & intensification of food and plantation crops - Policy measures tax incentive/ subsidies, free market - Development of early warning systems.
Water Resource	- Protection of groundwater resources - Improved management and maintenance of existing water supply systems - Protection of water catchment areas - improved water supply - Groundwater and rainwater harvesting and desalination	- Better use of recycled water - Conservation of water catchment areas improved system of water management - Water policy reform including pricing and irrigation policies - Development of flood controls and drought monitoring

Source (Unfccc, 2007)

1.1.1.2. Resilience

Adapting to climate change will entail adjustments and changes at every level-from community to national and international. Communities must build their resilience, included adopting appropriate technologies while making the most of traditional knowledge, and diversifying their livelihoods to cope with current and future climate stress. Local coping strategies and traditional knowledge need to be used in synergy with government and local interventions. The choice of adaptation interventions. But the choice of adaptation interventions depends on national circumstances. To enable workable and effective circumstances. To enable workable and effective adaptation measures, ministries and governments, as well as institution and NGOs, have to consider intergrading climate change in their planning and budgeting in all levels of decision making.

Resilience can be described as the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk, and recover from shocks. At first approximation, resilience is the contrary of vulnerability, but importantly it adds a time dimension to the concept: a system is resilient when it is less vulnerable to shocks *across time*, and can recover from them (Vincent & Alexandre, 2012).

Box 3. Resilience Definition
Resilience ‘’ ’The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation’’ (Arctic Council, 2013; IPCC, 2014).

Resilience : ‘’is the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions’’ (IPCC, 2012; Vincent& Alexandre, 2012)

Resilience: ‘’The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization and the capacity to adapt to stress and change’’(IPCC, 2007; LDCEG, 2012).

To a great extent, increasing resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity. This can be achieved by reducing exposure, reducing sensitivity and increasing adaptive capacity, for every type of risk. It can a

ct in each domain, either biophysical, economic and social. One way to achieve better resilience is to reduce transmission of shocks between types of risks, between scales and between domains and to organize compensation between scales (for instance transport of feed) or between domains (for instance safety nets) to avoid cumulative and long-term effects. In this section we make an attempt to describe the bricks that can be used to build

Strategies for resilience (Vincent & Alexandre, 2012). There are three ways to build resilience which describe in Box 4.

Box 4. Three ways to build resilience
First way: Reduce exposure. There is a fundamental difference between climatic and non-climatic shocks in this regard because most of the shocks on-farm can be reduced at the source, or limited in their extension, contrary to climatic shocks. Here the best example is probably the eradication of rinderpest, which has totally suppressed a major risk for livestock and those depending on it.
Second Way: Reduce the sensitivity of systems to shocks. Sensitivity to drought can, for instance, be reduced by using drought-resistant varieties or keeping stocks of hay.
Third Way: Increase adaptive capacity. This includes considering the modifications of a system taking into account all the potential shocks and changes altogether (to take into account compensating, cumulative or exacerbating effects). But all of this is not enough. To ensure resilience, the three ways of actions above have to be considered ***through time,*** and given ***uncertainties.*** (Vincent & Alexandre, 2012).

1.1.1.3. Importance of CCA

Adaptation is possible adjustments, spontaneous or planned, of people, plants, ecosystems, etc. to climate change to reduce adverse impacts, to take advantage of opportunities or to cope with the consequences of climate change. While reducing GHG emissions is vital for addressing climate change, in particular in a long-term perspective, adaptation allows immediate coping with climate change impacts to minimize damage. Even if GHG concentrations in the atmosphere were reduced, climate change would still occur due to the inertia of the climate system, and the already large quantities of GHG emitted over the past 200 years (MOE, 2004).

Adaptation to global warming is a response to climate change that seeks to reduce the vulnerability of social and biological systems to climate change effects. Even if emissions are stabilized relatively soon, climate change and its effects will last many years, and adaptation will be necessary. Climate change adaptation is especially important in developing countries since those countries are predicted to bear the brunt of the effects of climate change(Wikipedia., 2015).

Adaptation is a necessary strategy. Because of the current and projected climate disruption precipitated by high levels of greenhouse gas emissions by the industrialized nations, adaptation is a necessary strategy at all scales to complement climate change mitigation efforts because we cannot be sure that all climate change can be mitigated. And indeed the odds are quite high that in the long run more warming is inevitable, given the high level of GHGs in the atmosphere, and the (several decade) delay between emissions and impact.

Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages. Extremes, variability, and rates of change are all key features in addressing vulnerability and adaptation to climate change, not simply changes in average climate conditions.

Human and natural systems will to some degree adapt autonomously to climate change. Planned adaptation can supplement autonomous adaptation, though there are more options and greater possibility for offering incentives in the case of adaptation of human systems than in the case of adaptation to protect natural systems (Wikipedia., 2015).

1.2. Vulnerability and Adaptation Assessment

1.2.1. Definition of vulnerability to climate change

The term vulnerability is widely used in difference disciplines, because of the differences in their study objects and knowledge background, the understanding and definition of vulnerability can be vary difference. Vulnerability was originally used in the field of disaster studies to represent the extent of the injury. Later, with the growing influence of climate change issues the concept was introduced to the field of climate science, and the IPCC First Assessment Report provided a preliminary elaboration of it. 1996, the IPCC Second Assessment Report gave the definition of sensitivity and vulnerability. Later on in 2001, the IPCC Third Assessment Report clearly defined the relationship among climate change sensitivity and adaptation and vulnerability(Tao *et al.*, 2011).

$$\mathbf{Vulnerability} = \mathbf{f}(\mathbf{Exposure}, \mathbf{Sensitivity}, \mathbf{Adaptive\ Capacity})$$

Box: 8. Definition of vulnerability

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Vulnerability: is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system (IPCC, 2007) .

Vulnerability: of a system refers to its physical, social, and economic aspects. According to IPCC, vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed; its sensitivity; and adaptive capacity(IPCC, 2001a)

Global s and change has become a major environmental problem affecting the future survival and the development of mankind, and it has attracted widespread attention of governmental organization and academic community in the world. Agriculture is one of the sectors most sensitive to climate change, and any degree of climate change (Tao *et al.*, 2011).

we can note that IPCC uses three terms to define vulnerability exposure, sensitivity, and adaptive capacity. Vulnerability in this context can be defined as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard. The concept is relative and dynamic. Vulnerability is most often associated with poverty, but it can also arise when people are isolated, insecure and defenseless in the face of risk, shock or stress. People differ in their exposure to risk as a result of their social group, gender, ethnic or other identity, age and other factors. Vulnerability may also vary in its forms: poverty, for example, may mean that housing is unable to withstand an earthquake or a hurricane, or lack of preparedness may result in a slower response to a disaster, leading to greater loss of life or prolonged suffering. The reverse side of the coin is capacity, which can be described as the resources available to individuals, households and communities to cope with a threat or to resist the impact of a hazard. Such resources can be physical or material, but they can also be found in the way a community is organized or in the skills or attributes of individuals and/or organizations in the community. To determine people's vulnerability, two questions need to be asked:

- To what threat or hazard are they vulnerable?
- What makes them vulnerable to that threat or hazard?

Cambodia is one of the most disaster-prone countries in East Asia, with its vulnerability to annual floods and droughts. One of the reasons why it is vulnerable to natural disasters is that the livelihoods of the majority of people depend directly upon natural resources, with a large proportion of its population occupied in agriculture and related sectors, including animal husbandry. Extreme poverty, which limits access to food, water, and other basic amenities, increases vulnerability.

The frequency and intensity of floods may increase with changing climate conditions, and cause severe damage to rice harvests. Successions and combinations of droughts and floods have resulted in a significant number of fatalities and considerable economic losses. Losses arising from floods have been further exacerbated by deforestation. Floods have accounted for 70% of rice production losses between 1998 and 2002, while drought accounted for 20% of losses (MoE, 2006).

Flood and rainfall patterns play a determining role in paddy cultivation and the absence of widespread irrigation and water harvesting schemes in Cambodia make this sector particularly vulnerable to climate change, especially due to the effects of flooding and drought

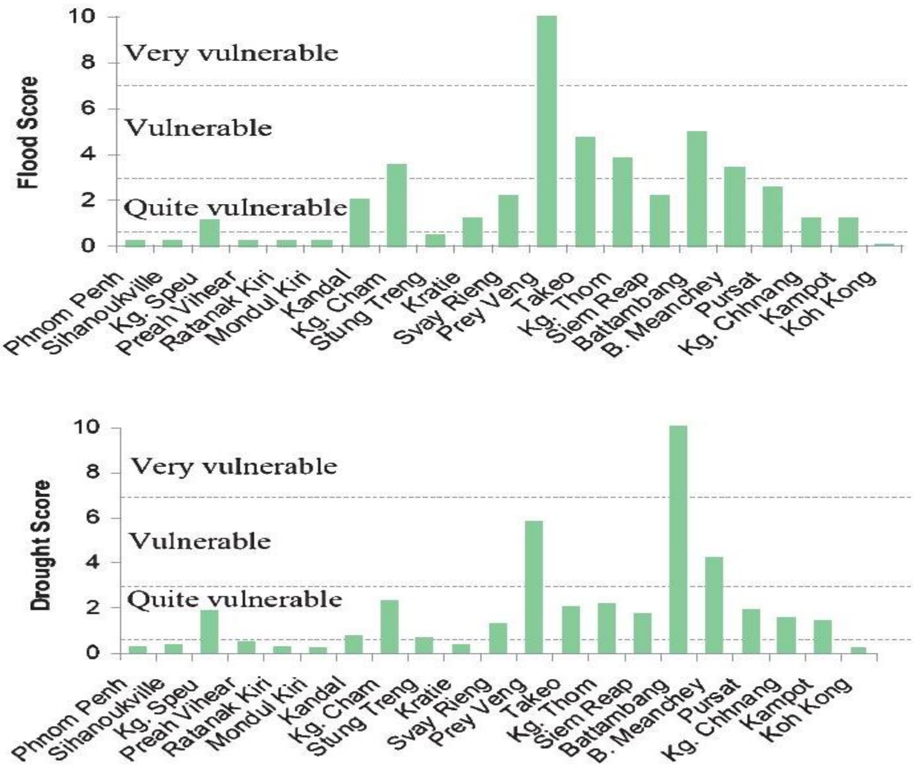

Figure 1:Vulnerability level to floods and droughts by provinces, Cambodia
Source :(MoE, 2006)

1.2.1.1. Climate Hazards and Extreme Events Key Vulnerabilities, Risks, and Reasons for Concern

In an effort to provide some insights into the seriousness of the impacts of climate change WGII TAR (Chapter 19) identified five ‘‘Reasons for Concern’’ (RFC) focusing on (1) unique and threatened systems, (2) extreme climate events, (3) distribution of impacts, (4) aggregate impacts, and (5) large-scale discontinuities (see Figure 5). Considering new evidence of observed changes on every continent, coupled with more thorough understanding of the concept of vulnerability, the AR4 concluded that the five “reasons for concern identified in the TAR remained a viable framework to consider key vulnerabilities” .

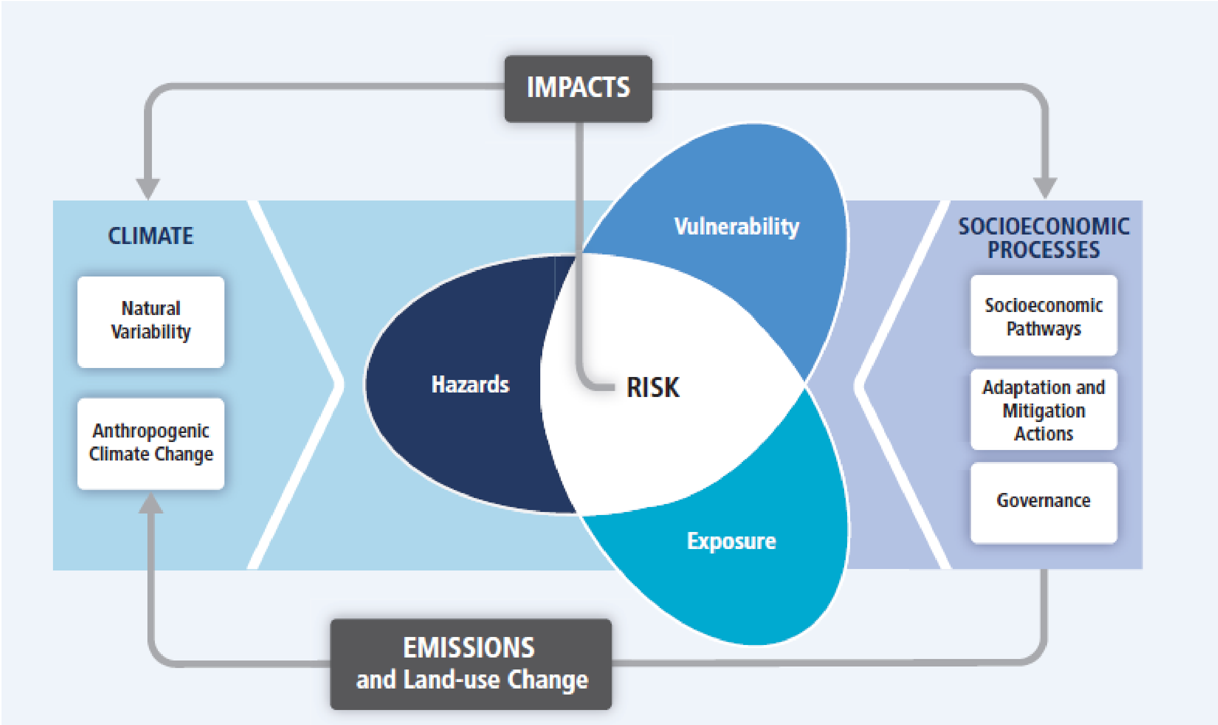

Figure 2: Core concepts of the WGII AR5 (IPCC, 2014). Risk of climate-related impacts results from the interaction of climate-related hazards

Impacts: Effects on natural and human systems. the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts (IPCC, 2014).

1.2.1.2. Sensitivity and Exposure

There are many concepts of sensitivity and exposure. **Exposure** refers to the extent and the characteristics as a system exposed to significant climate variability, **Sensitivity** refers to the degree of influence as a system stimulated by climate-related factors, including the adverse and beneficial effects. and **adaptive capacity** refers to ability of making profit and avoiding loss as the natural and man-made system affected by actual or expected climatic stimuli and their impacts(Tao,S *et al.*, 2011)

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected. The **Exposure** is what is at risk from climate change, e.g.,

- Population
- Resources
- Property

It is also the climate change that an affected system will face, e.g.,

- Sea level
- Temperature
- Precipitation
- Extreme events

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise). *Sensitivity*

- Biophysical effect of climate change
  - Change in crop yield, runoff, energy demand
- It considers the socioeconomic context, e.g., the agriculture system
- Grain crops typically are sensitive
- Manufacturing typically is much less sensitive

1.2.1.3. Adaptive Capacity

The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. Capability to adapt to climate change with the function of: Wealth, Education, Institutions, Information, Social capital, Technology, Infrastructure. Having adaptive capacity does not mean it is used effectively (MoE, 2002).

For example of adaptive capacity in Africa indicated that this country has a low adaptive capacity to both climate variability and climate change exacerbated including low GDP per capita, widespread endemic poverty, weak institutions, low levels of education, low levels of primary health care, little consideration of women and gender balance in policy planning, limited access to capital including markets, infrastructure, and technology, ecosystems degradation, complex disasters, conflicts (Unfccc, 2007).

For instance, in Latin America, (Unfccc, 2007) showed that adaptive capacity of this country has improve in some social indicators such as: life expectancy, adult literacy and freshwater access. However, adaptive capacity is limited by high infant mortality, low secondary school enrolment and high levels of inequality both income and in access to fresh water and health care as well as gender inequalities.

Case example of vulnerability framework in Moldova

The framework defines vulnerability as a function of exposure, sensitivity and adaptive or coping capacity. The advantage of this approach is that it helps distinguish between what is exogenous, what is the result of past decisions and what is amenable to policy action.

Vulnerability, broadly speaking, is the degree to which a system is likely to experience harm due to exposure to a hazard (Turner et al 2003). *Exposure* is a fairly straightforward concept: it is determined by the type, magnitude, timing and speed of climate variation to which a system is exposed (e.g. changing onset of the rainy season or minimum winter temperatures, floods, storms, heat waves). But the impact of a climate shock or change also depends on how *sensitive* a system is to that particular shock. The impact of a flood, for example, will depend on whether people live in the flood plain, toxic waste or water treatment plants have been sited in the flood plain, and/or the municipality has the organizational and financial resources to take the needed actions to avoid the spread of waterborne diseases, help people access shelter, and quickly rebuild washed-out infrastructure thereby reducing post-disaster loss of life and promoting faster recovery. Together exposure and sensitivity determine the *potential risk* confronting a community or a system – the impacts without considering planned adaptation.

Vulnerability also depends on *how capable a system is to adapt* and become better equipped to cope. Adaptation can be planned or autonomous, it can be anticipatory or reactive. But generally speaking the ability of systems (human, physical, social) to adapt is largely determined by how stretched they are. A system that is already close to its limits (e.g. a congested and poorly maintained transport system; a population in ill health with many vulnerable individuals; a water basin that has close to exhausted its underground water resources) or is already poorly managed will suffer great damages even from small shocks. The ability to adapt is also a function of organizational skills, access to and ability to use timely information, and access to financing.

The distinction between sensitivity and adaptive capacity can get blurry. Sensitivity can be thought of as the degree to which a system is affected (positively or negatively) *in its current form* by a climate trend, climate variability or a climate shock. Instead adaptive capacity is dynamic and affects future sensitivity. In practice, however, it may well be that the same factors that determine current sensitivity contribute to determine the extent of capacity to adapt.

The interest of the exposure/sensitivity/adaptive capacity approach is that it helps identify the factors that combine to amplify or reduce the impact of climate change and distinguish what are exogenous factors (exposure) as opposed to those that are amenable to local policy actions (adaptive capacity hence future sensitivity). It can be applied sector by sector or to particular regions or cities.

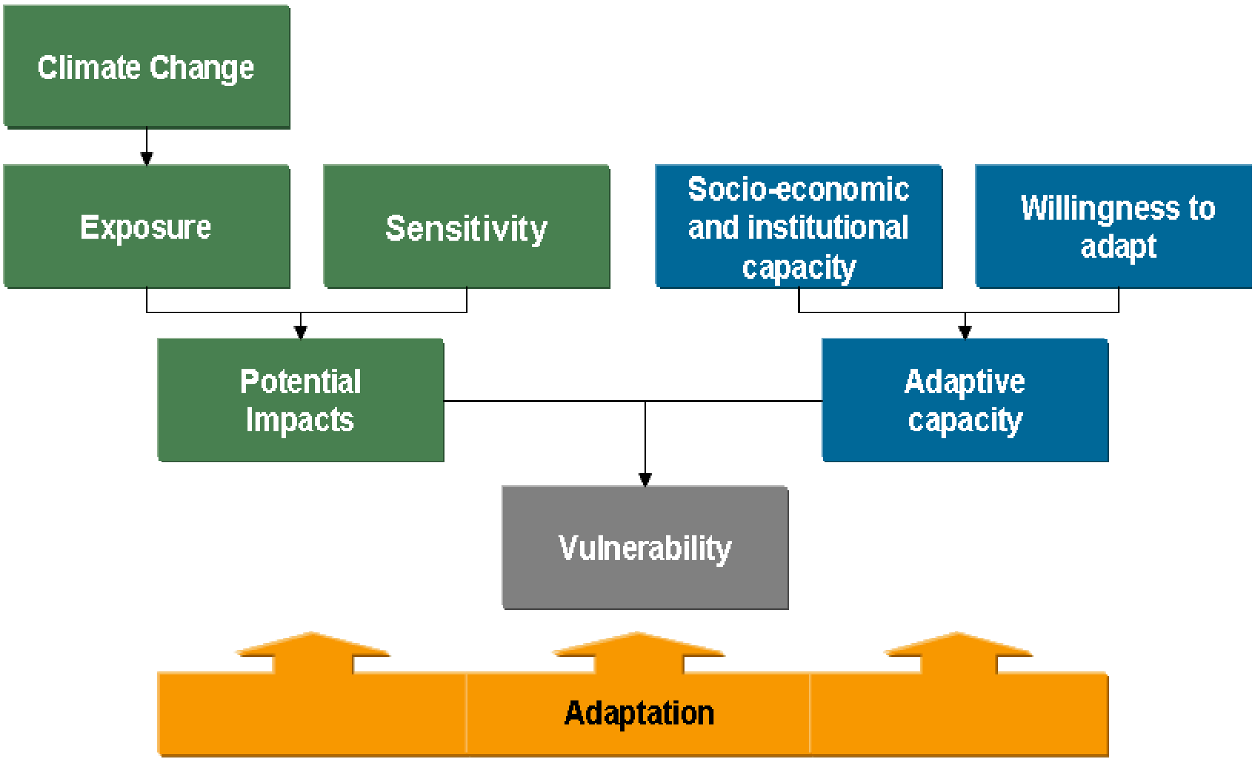

Figure 3: Vulnerability Framework

Impact and vulnerability assessments are important for providing the evidence to make decisions on the priority areas requiring investment and the nature of those investments. It is important to ensure that evidence is generated using both bottom-up techniques (e.g. community vulnerability assessments and engagement with sub-national stakeholders) as well as topdown studies (e.g. sector-wide climate impact studies) (AMCOW, 2012) To understand how impact and vulnerability studies can assist in decision making, it is important to understand climate variability and how this relates to vulnerability and climate impacts.

The climate – including rainfall, temperature and wind speed – varies year on year, month on month, and on daily timescales. This presents risks for human societies and systems, which must be able to operate successfully in the face of this variability. When variability causes systems to fail, for example a flood destroying a bridge, or a long-term drought reducing crop yields, systems are described as vulnerable to climate variability. When systems cope with such climate variability, they are said to be resilient. (AMCOW, 2012).

Vulnerability is dependent on the adaptive capacity of the system and the impact of the variability on the system. Impact is itself a function of the exposure and sensitivity of the system to climate variability. Exposure refers to the characteristics of the variability itself, for example storms, heavy rainfall, drought or flooding, and the magnitude and frequency of occurrence. For example, some regions are highly exposed to cyclones while others are exposed to highly variable seasonal rainfall (AMCOW, 2012).

Sensitivity of the system refers to its characteristics, which interact with the exposure to cause impact. For example, rainfed agriculture is highly sensitive to rainfall variability (some crops more than others). Therefore rainfed agriculture combined with an exposure to variable seasonal rainfall is likely to result in a high level of climate impact on the agricultural system, for example through variability in year-on-year crop yields.

Adaptive capacity refers to the characteristics of the system that allow it to cope with climate variability. These might include assets, policies and knowledge that support systems in the face of variability. One example of adaptive capacity is the presence or absence of drought monitoring and response systems in areas prone to climate variability. Such systems help farmers to plan their activities and reduce the negative impacts of climate variability. Impact assessment is mainly concerned with the exposure and sensitivity of systems to climate, whereas vulnerability assessments focus on how systems cope and adapt to impacts. Other frameworks describe vulnerability as risk, and adaptive capacity as vulnerability. For example, disaster risk uses a framework that describes risk as a function of the climate hazard and vulnerability of the system.

Climate change may alter the nature of the physical exposure of human systems to climate variability through changes in both the long-term climate (e.g. average annual rainfall) or changing the nature of variability (e.g. more intense storms, irregular seasonal rainfall). Socio-economic changes may put pressure on human systems that are influenced by the climate; for example, population growth in cities may increase their sensitivity to water shortages. Socio-economic change may also present opportunities for reducing risks, for example through improved communication systems(AMCOW, 2012).

Vulnerability and impact assessments can feed into adaptation assessments. These are designed to determine the activities that should be undertaken to address the risks identified.

1.2.2. Vulnerability assessments

Generally take a bottom-up approach, focusing on the factors that make different people or places vulnerable to current and future climate risks. While they can be developed at local or broader scales, they focus on exposure to climate hazards and how to reduce vulnerability. A key question often answered by vulnerability assessments is: What are the characteristics of the society, economy and/or environment that cause climate variability to have a negative or positive impact? (AMCOW, 2012).

Vulnerability Assessment examine the underlying socioeconomic and institutional factors, and, to a lesser extent, political and cultural factors that determine how people respond to and cope with climate hazards (Adger et al. 2004:6). These assessment are a useful tool with which to assess people’s needs for adaptation. Vulnerability assessments do not require detailed climate information generated by models and they do not require us to wait until the science of climate prediction is more developed (Adger et al. 2004:6).

Vulnerability assessments aim at identifying selected determinants, sometimes to quantify them for comparative purposes, and they may also be performed to study the capacity of a system to cope or adapt to a stress (MRC 2010b:8). Downing and Patwardhan (2004 cited in MRC 2010b:8) list the following outputs of vulnerability assessments:

- A description and analysis of present vulnerability, including representative vulnerable groups (for instance specific livelihoods at risk of climatic hazards)
- Description of potential vulnerabilities, including an analysis of pathways that relate the present to the future
- Comparison of vulnerability under different socioeconomic statuses, climatic changes and adaptive responses.

1.2.3. Adaptation assessments

Go beyond impact and vulnerability assessments to look at potential solutions to address impacts and vulnerabilities. The Framework can be viewed as a form of adaptation assessment, within which impact and vulnerability assessments are used to inform decision making on adaptation. Adaptation assessments are typically more focused on the need to support near-term decisions (5–10 years) and concerned with current risks and the promotion of flexible strategies, given the deep uncertainties about future climate and socio-economic change. A key question often answered by adaptation assessments is: What changes can be made to the society, economy and/or environment that will reduce vulnerability and the negative impacts of climate change and variability? (AMCOW, 2012).

Adaptation Assessment is the process of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility (IPCC 2001a:982).

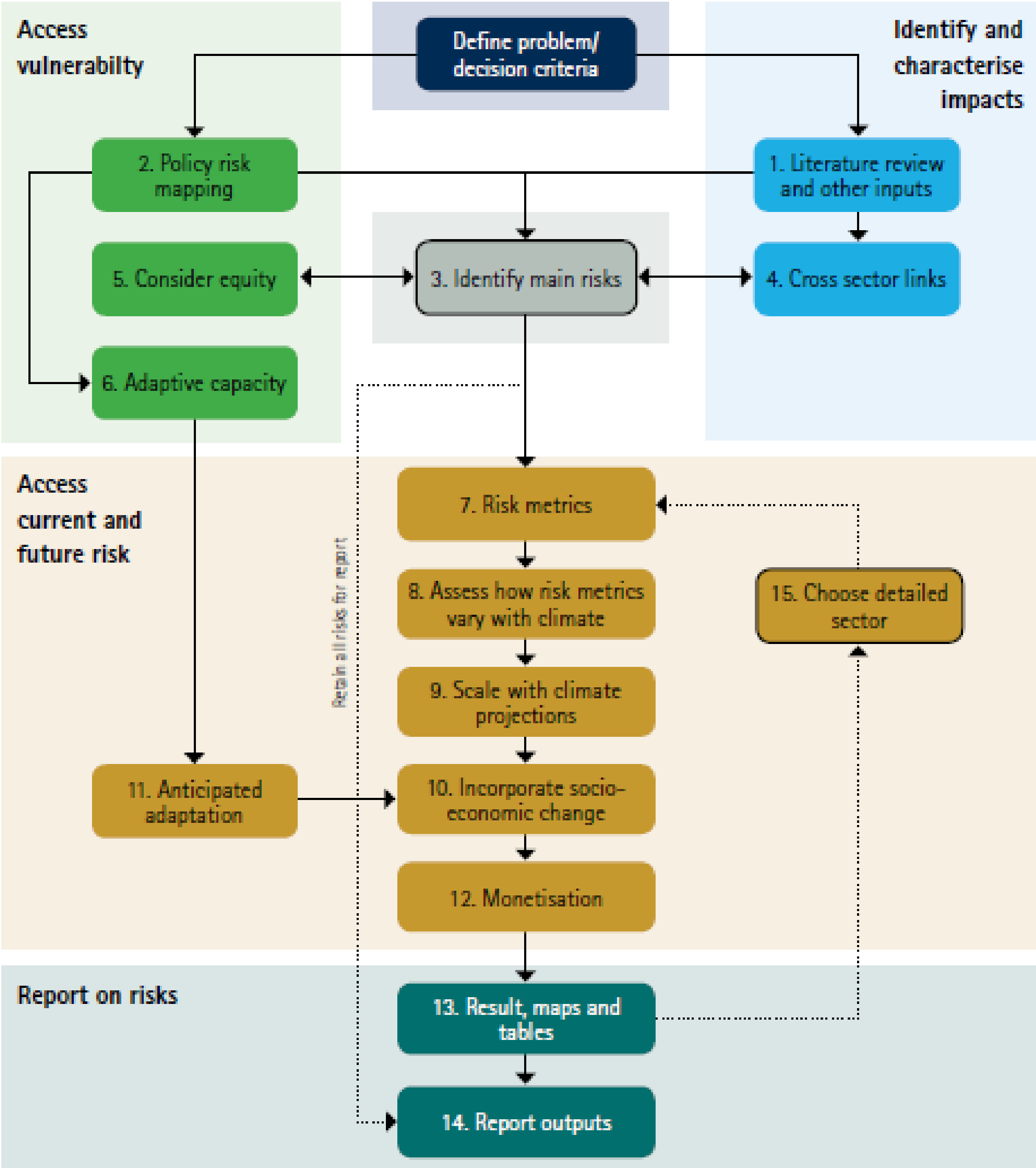

Figure 4: The UK Climate Change Risk Assessment methodological framework

Source: (AMCOW, 2012).

1.2.4. Climate Change Scenario

What are Climate Change Scenarios?

Scenarios are often used to assess the consequences of possible future conditions, how organizations or individuals might respond, or how they could be better prepared for them. For example, business might use scenarios of future business conditions to decide whether some business strategies or investments make sense now.

Climate Change scenarios is important because it can determine the outcome of a climate change impacts analysis. Extreme scenarios can produce extreme results, and moderate scenarios can produce moderate result. Climate Change scenarios have been typically developed for a particular point in the future. Many climate change scenarios examine the climate associated with a doubling of carbon dioxide levels in the atmosphere over pre-industrial levels ($2xCO_2$).

Climate Change scenarios are scenarios of plausible/believable changes in climate. We use them to understand what the consequences of climate change can be. We can also use them to identify and evaluate adaptation strategies. We create climate change scenarios because prediction of climate change at the regional scale have a high degree of uncertainty.

Selecting the climate change scenarios must follow the conditions. For impact assessment should meet the four conditions:
Condition 1: The scenarios should be consistent with the broad range of global warming projection based on increased atmospheric concentrations of greenhouse gases.
Condition 2: The scenarios changes in variables need to be physically consistent with each other. For example, days with increased precipitation will most likely have increased cloudiness.
Condition 3: The scenarios should estimate a sufficient number of variables for impacts assessment number of meteorological variables such as temperature, precipitation, solar radiation, humidity, and wind.
Condition 4: The scenarios should, to a reasonable extent, reflect the potential range of future regional climate change For example, a set of scenarios that examines only a relative large or small amount of warming, or only wet or dry condition, will not help identify the full range of sensitivities to climate change.

From the projection analysis in Cambodia, the greenhouse gas emissions and removals by sectors show that in 2000, the country was already a net emitter of GHGs. This net emissions were approximately 6,244 Gg of CO_2 –eqv. The net emissions would be increase in 2020 approximately 43,848 Gg of CO_2 –eqv. Amoung the sectors, LUCF would be the main source of GHG emissions (63.0%), follow by agriculture(27.5%). Energy would only contribute to approximately 9.0% of the total national emissions (MoE, 2002) .

In agriculture sector, projection indicated that GHG emissions from agriculture would increase quite significantly. In 2020, methane emissions will be about three times the 1994 emissions while nitrous oxide will approximately double. The rate of increase in methane emissions for livestock would be slightly higher than that from rice paddy. In total, GHG emissions from agriculture in 2000, 2010 and 2020 would be approximately (12,030) , (17,789) and 26,821 Gg of CO_2 –eqv.

By (AMCOW, 2012) taken the definition from the third assessment report of the Intergovernmental Palnel on Climate change(IPCC) include as special report on Emissions Scenarios(SRES), define Scenarios as ‘’*a plausible description of how the future may develop, based on o coherent and internally consistent set of assumptions(scenario logic) about key relationships and driving force(e.g. rate of technology change, prices). Note that scenarios are neither predictions nor forecasts.’’*

What is a scenario for?

Box 10. What is a scenario for?

Scenarios provide representations of potential future situations; .If we could accurately predict the future, then planning would require only a single scenario. In reality the future is uncertain and more than one scenario must be considered. Scenarios are required for planning purposes, in order to specify assumptions about the conditions that planned investments will need to respond to in the future. For example, scenarios of water demand and population are often combined with scenarios of climate change, to facilitate better planning for future investments in water supply systems. The creation of a set of scenarios is an attempt to boil down the myriad possible future conditions into a manageable number of scenarios that encompass the major uncertainties. The Intergovernmental Panel on Climate Change (IPCC) developed 40 socio-economic scenarios as the basis for estimating emissions of greenhouse gases, six of which are commonly used to capture the full range of future emissions (these six are known as A1F1, A1B, A1T, A1, A2 and B2). These IPCC scenarios are described in the Special Report on Emissions Scenarios (SRES) and form a useful international benchmark for high level projections of socio-economic development. Figure 8

Economic emphasis

global integration →

A1 storyline **World:** market-oriented **economy:** fastest per capita growth **Population:** 2050 peak, then decline **governance:** strong regional interactions; income convergence **technology:** three scenario groups: • **a1Fi:** fossil intensive • **a1t:** non-fossil energy sources • **a1b:** balanced across all sources	A2 storyline **World:** differentiated **economy:** regionally oriented; lowest per capita growth **Population:** continuously increasing **governance:** self-reliance with preservation of local identities **technology:** slowest and most fragmented development
B1 storyline **World:** convergent **economy:** service and information based; lower growth than A1 **Population:** same as A1 **governance:** global solutions to economic, social and environmental sustainability **technology:** clean and resource efficient	B2 storyline **World:** local solutions **economy:** intermediate growth **Population:** continuously increasing at lower rate than A2 **governance:** local and regional solutions to environmental protection and social equity **technology:** more rapid than A2; less rapid, more diverse than A1/B1

Figure 5: The four standard SRES scenarios

Source: (AMCOW, 2012)

Box 11. Example of simple climate change scenarios for Cameroon

Based on the UNDP's country profiles, simple climate scenarios can be developed rapidly to give an indication of future trends. Temperature projections for Cameroon indicate temperature increases of 1.5 to 4.7°C by the 2090s. Rainfall projections are less certain, with anticipated changes in annual rainfall of between approximately -7% and +20% (based on 1970–1999 averages and the maximum

	Rainfall decrease of 7%	No Change in rainfall	Rainfall increase of 20%
Temperature increase of 1.5 oC	A- Warm/dry	C- Warm	E- Warm/Wet
Temperature increase of 4.7 oC	B- Hot/dry	D- Hot	F- hot/wet

If the project or programme is sensitive to storm rainfall, then simple scenarios can be developed based on changes in maximum rainfall intensity. The UNDP projects a maximum increase of approximately 20% in rainfall intensity by 2090. If the project or programme is sensitive to a rise in sea level, then simple scenarios based on the level of the projected rise can be developed. The projections range between 0.13 and 0.56 meters by 2090. Sea level rise may also have implications for coastal processes such as erosion and accretion. The UNDP country profiles are available online via the country pages of the UNFCCC National Communications Support Programme, available at: http://ncsp.undp.org/

Box 12. Case study of the use of scenarios for climate change, water and agriculture in the Greater Mekong sub region

This case study provides an example of a qualitative impact assessment of climate and non-climate drivers on water resources, including a discussion of potential priorities. This study reviews the existing relevant body of research and uses expert judgment to qualitatively assess the key impacts of climate and non-climate drivers on the Greater Mekong sub region.

Existing conditions – A review of the current status and trends in the water and agriculture sectors is presented in order to set a baseline.

Climate scenarios – Climate change scenarios (including river flow and sea level rise) are drawn from preceding academic studies rather than directly from climate change databases. These scenarios are compared and contrasted to give an overall qualitative picture of the uncertainties involved.

Non-climate scenarios – Population growth, trends in diet, investment and trading patterns and projections are discussed based on various sources.

Regions – The Greater Mekong is the sub-region of interest, but scenarios derived from other studies have been developed, which do not entirely overlap with this region. Particular areas within the region are discussed if they are considered to be subject to particular risks.

Modelling – No modelling is carried out in this impact assessment; instead the approach is to review more detailed studies and use expert judgment to provide a qualitative weighting of the importance of different challenges.

Uncertainty – Qualitative impressions of the relative uncertainty and importance of different drivers are provided throughout but no attempt is made to quantify these. This is likely to be beyond the scope of this discursive (non-technical) study.

Further analysis – In addition to assessing the likely impacts of climatic and non-climatic drivers on the Mekong sub-region, expert judgments is utilized to highlight potential priority areas for adaptation activities.

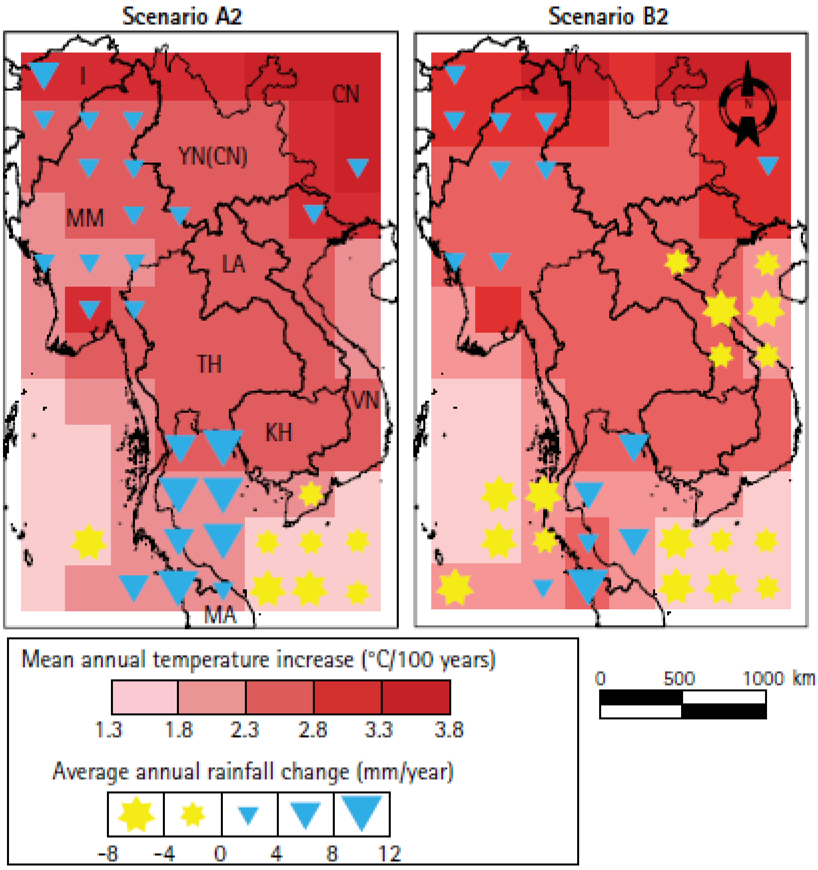

Figure 6: Projected changes in temperature and rainfall in the Greater Mekong sub-region, 1960–2049

Source: (AMCOW, 2012)

1.3. Climate Change Adaptation Action

1.3.1. National Adaptation Program of Action (NAPA)

1.3.1.1. Concept of NAPA

A National Adaptation Programme of Action (NAPA) is one of the types of reporting envisaged by the United Nations Framework Convention on Climate Change(UNFCCC) (UNFCCC, 2014c). They are prepared by Least Developed Countries, to describe the country's perception of its most "urgent and immediate needs to adapt to climate change"(UNFCC, 2014; Wikipedia., 2013). NAPAs are not supposed to include original research, but use existing information and include profiles of priority projects that are intended to address those needs that have been identified.

The UNFCCC maintains a database of NAPAs, (UNFCCC, 2014b) and of country priorities that have been identified within NAPAs. (UNFCCC, 2014a).As of November 2011, it contained reports from 46 LDCs.

The Least Developed Country Fund (LDCF) was established to finance the preparation of NAPAs and to implement the projects that they propose. (GEF, 2014) The LDCF currently has resources of at least US$415 million, of which US$177 million has been approved for 47 projects, attracting more than US$550 million in co-financing in the process (Wikipedia., 2013). The NAPA project is funded by the international donor community through its contributions to the Global Environment Facility (GEF).

The identification of priority adaptation activities is the main goal of the NAPA formulation exercise. The formulation of the NAPA follows a participatory process that involves those who are most affected by climatic impacts, that is rural people and the poor. The NAPA builds upon existing coping strategies implemented by local communities in order to enhance their adaptation capacity. More specifically, the objectives of the NAPA project are: (1) to understand the main characteristics of climate hazards in Cambodia (flood, drought, windstorm, high tide, salt water intrusion and malaria); (2) to understand coping mechanisms to climate hazards and climate change at the grassroots level; (3) to understand existing programmes and institutional arrangements for addressing climate hazards and climate change; (4) to identify and prioritize adaptation activities to climate hazards and climate change (MoE, 2006).

1.3.1.2. NAPA Implementation

As a least developed agrarian country, Cambodia is highly vulnerable to climate change, the more so as it has low adaptive capacity to changing climate conditions. In recent years, we have witnessed more frequent and severe floods and droughts, which have resulted in a significant number of fatalities and considerable economic losses. For this reason, we have recently taken our first steps in developing a Cambodian National Adaptation Programme of Action to Climate Change (NAPA) (MoE, 2006).

The main goal of the Cambodian NAPA is to provide a framework to guide the coordination and implementation of adaptation initiatives through a participatory approach, and to build synergies with other relevant environment and development programmes. Cambodia's NAPA presents priority projects to address the urgent and immediate needs and concerns of people at the grassroots level for adaptation to the adverse effects of climate change in key sectors such as agriculture, water resources, coastal zone and human health.

The Cambodian NAPA is supportive of the Government's development objectives as outlined in the
"Rectangular Strategy for Growth, Employment, Equity and Efficiency" adopted in July 2004, as well as in the "National Strategic Development Plan 2006-2010 (NSDP)" adopted in May 2006. Both the Rectangular Strategy and the NSDP 2006-2010 stress the need to improve agricultural productivity through the expansion of irrigation and the management of water resources to reduce vulnerability to natural disasters. All concerned ministries and agencies shall make their utmost efforts to integrate the priority projects identified in this National Programme into their respective sectoral plans.

Implementation of the Cambodian NAPA will significantly contribute to the achievement of the Cambodia Millennium Development Goals and national sustainable development objectives as articulated by the Royal Government of Cambodia. Therefore, our next task is to mobilize resources, to establish a mechanism for inter-ministerial cooperation, coordination and monitoring for the implementation of this Programmed, and to raise awareness on climate change issues, including on NAPA. Involvement of all key stakeholders - vulnerable groups, commune councils, concerned Government ministries and agencies, NGOs, and donor agencies - is a prerequisite for the successful implementation of NAPA. It is our hope that the commitment of Cambodian stakeholders will elicit a similar commitment by the international community(MoE, 2006).

Having recognized adverse impacts of climate change on social and economic development, the environment and livelihoods, in particular, those of poor rural communities, the Ministry of Environment has worked hard with other Government ministries and agencies, and donor partners to formulate a Cambodian NAPA. This is a realistically achievable country-driven programme of action and priority activities addressing the urgent and immediate needs and concerns of the country for adaptation to the adverse effects of climate change. Through a series of consultations from the grassroots to policy-makers, national and provincial workshops, stakeholder interviews and surveys of rural communities, we have identified 39 adaptation projects in key sectors such as agriculture, water resources, coastal zone, and human health. These are "no-regrets" adaptation options that can be divided into three categories: (i) capacity building/training (ii) awareness raising/education, and (iii) infrastructure development. The proposed projects include: the construction of community water reservoirs, the development and improvement of community irrigation systems, the rehabilitation of coastal protection infrastructures, reforestation activities, the local production of bio-pesticides for mosquito control, the wider distribution of mosquito nets, and other much needed initiatives that will allow Cambodia to both adapt to climate change and achieve its national sustainable development objectives(MoE, 2006).

National Adaptation Programmed of Action to Climate Change (NAPA) aims to develop a realistically achievable country-driven programmed of action and priority activities addressing the needs of Cambodia for adapting to the adverse effects of climate change (MoE, 2006; UNDP, 2003).

A number of barriers to the implementation of the NAPA have been identified. These include: (i) inadequate technical, financial and institutional capacity of Government agencies and of local communities in dealing with climate hazards Government agencies, and limited coordination among them; (ii) limited integration of climate change issues into national policies and programms; and (iii) limited awareness of climate change issues.

1.3.1.3. Projects at National Level

In preparing the Cambodian NAPA, the Ministry of Environment has made its utmost efforts to use the most recent official and existing data of the RGC and concerned ministries and agencies. In addition, we have collected missing data for preparing this document.

1.3.2. National Adaptation Plan (NAP)

1.3.2.1. Introduction

Climate change is one of the many challenges that developing nations face as they plan for the future. The 2014 Intergovernmental Panel on Climate Change (IPCC) reinforces findings that climate change impacts are already being felt and are projected to intensify across all continents.

Climate change impacts impose risks to human health, welfare, and ecosystems, and threaten important development goals such as reducing poverty, increasing access to education, improving child health, and managing natural resources sustainably. People – and countries – who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are especially vulnerable to climate change (IPCC, 2014; USAID, 2014). By addressing climate threats in the context of their development goals, developing countries can build resilience to climate change and improve their development outcomes.

National adaptation planning is a critical component of climate resilient development. While many adaptation actions will be taken at a local level, it is at the national level that priorities for development and adaptation are set, and coordination is conducted with donors. National governments also make many important decisions regarding taxes, expenditures, regulations, land-use, and other aspects of national policy making that can profoundly affect a nation's development path. Thus, developing a national plan presents a critical opportunity for nations to incorporate increased resilience to climate change into national development (USAID, 2014).

Adapting to climate change is becoming a routine and necessary component of planning at all levels. The United Nations Framework Convention on Climate Change (UNFCCC) established the national adaptation plan (NAP) process as a way to facilitate adaptation planning in least developed countries (LDCs) and other developing countries (UNFCC, 2012).

1.3.2.2. NAP Guidelines

The Conference of the Parties (COP) to the UNFCCC acknowledged that national adaptation planning can enable countries to assess their vulnerabilities, to mainstream climate change risks, and address adaptation. The COP also acknowledged that, because of the level of development of LDCs, climate change risks magnify development challenges for LDCs. It recognized the need to address adaptation planning in the broader context of sustainable development planning(UNFCC, 2012)

1.3.2.3. NAP process

In 2010, the parties to the UNFCCC established the NAP process under the Cancun Adaptation Framework (see Figure 22). This planning process can be used to integrate the consideration of climate change impacts into the development planning process, and ensure that decisions made today promote short- and long-term climate resilience and do not increase future vulnerability to climate change. NAPs should be based on nationally identified priorities, and coordinated with national objectives, plans, policies, and programs.
The UNFCCC Least Developed Countries Expert Group (LEG) developed NAP guidance in 2012 (UNFCCC, 2014). It presents a flexible, stepwise approach to carrying out national adaptation planning that includes assessing climate risks and vulnerabilities, identifying and prioritizing adaptation options, preparing national adaptation plans and implementation strategies, enhancing capacity, and creating procedures to monitor and report on progress.

Box 14. The Objective of NAP

The agreed objectives of the national adaptation plan process are:
(a) To reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience;
(b) To facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate

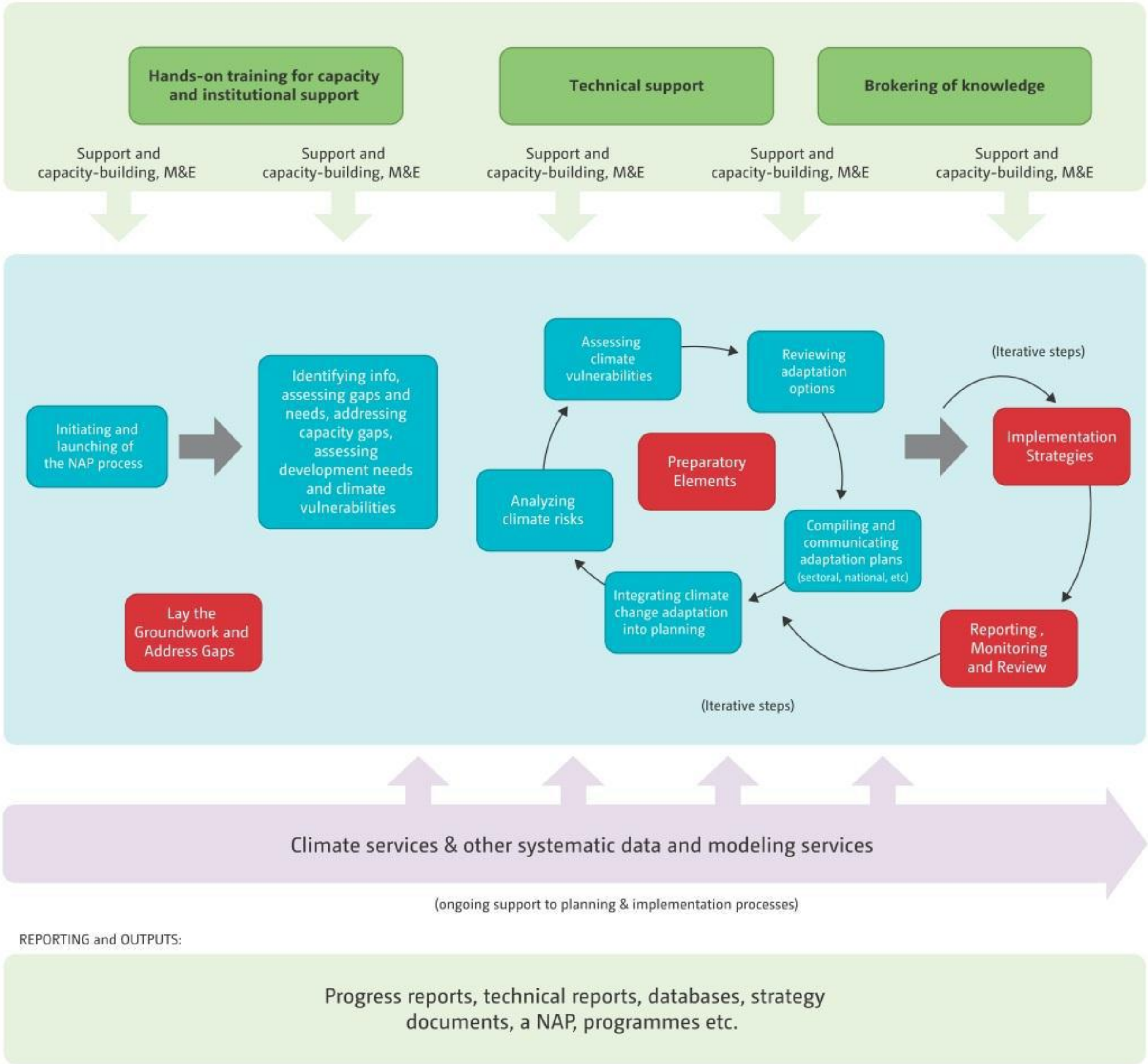

Figure 7: NAP Process

source: (UNFCC, 2012; USAID, 2014)

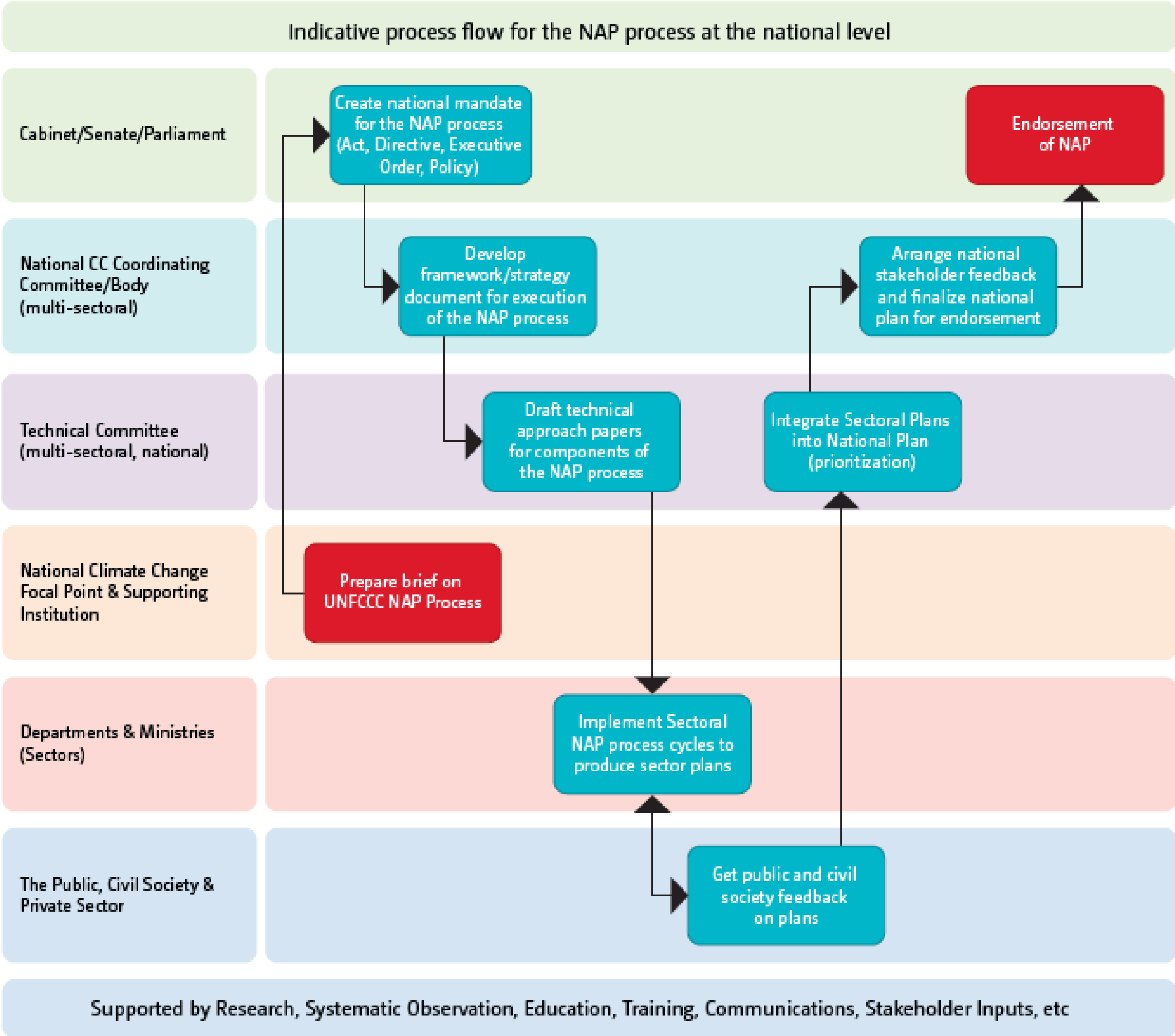

Figure 8: NAP Process at the national level

Source: (UNFCC, 2012; USAID, 2014)

1.4 Gender and Climate Change

1.4.1 Gender and Impact of Climate Change

Gender issues have been rarely addressed, particularly in relation to climate change impact in global climate change initiatives and policy meetings. Debates have focused primarily on mitigation efforts (reduction of carbon emissions and other greenhouse gases), and on the associated actions required by governments and institutions to mitigate climate change. Insufficient attention has been paid to climate change adaptation strategies – actions taken for and by people, to prepare and make changes to protect themselves against climate change. Adaptive actions are taken to reduce the threat to food supply, health and well-being, livelihoods and security. Women's roles are not adequately recognized or accounted for in climate change mitigation and adaptation efforts, in national and global climate change negotiation talks or in the context of natural disasters influenced or exacerbated by climate change.

Despite the guiding principles within the United Nations (UN) system to incorporate gender considerations, climate change policy-making (most visibly, the UN Framework Convention on

Climate Change, UNFCCC) has failed to adopt a gender-sensitive approach. This failure not only generates concerns in terms of respect for gender equity, it also leads to shortcomings in the efficiency and efficacy of climate-related adaptation and mitigation measures and instruments.

Vulnerability to climate change can exacerbate the impacts of non-climatic stressors such as increased migration, rapid urbanization, uncertain energy security, unsustainable management of natural resources and the loss of traditional coping mechanisms. Responding to climate change is not simply a matter of reducing the amount of greenhouse gas emissions into the earth's atmosphere, but is also about helping countries to build adaptive capacity and develop a sense of preparedness to reduce its negative impacts. In order to achieve this, it is important to understand the framework of analysis for gender and climate change that addresses vulnerabilities, adaptation, mitigation and the manner in which engagement can take place.

Compared to men, women are affected differently, and often more severely by climate change and associated natural disasters such as floods, droughts, cyclones and storms. This is largely because men and women are bound by distinct socio-economic roles and responsibilities that give rise to differences in vulnerability and ability to cope with these climate change consequences.

Women, particularly in least-developed Countries (LDCs) are disproportionately vulnerable because of their:

- dependence on bio-fuels and other natural resources;
- responsibility for water procurement and household care;
- role in securing food and fuel;
- predominant presence in low technology agriculture; and
- greater exposure to risk in crisis and severe weather events that may have been influenced or impacted by climate change.

Consequently, vulnerable groups – especially poor women – are likely to be faced with problems such as food insecurity, loss of livelihood, hardships due to environmental degradation that lead to displacement and a host of other potentially devastating economic and social consequences. It is poor women who are most vulnerable and will bear the adaptation burden despite their comparatively insignificant contribution to greenhouse gas emissions. In addition to these vulnerabilities women are still underrepresented in decision-making with respect to plans and actions to mitigate, and adapt to, climate change.

The dependency on biomass as the main fuel source in the rural areas of most developing countries means that women and children, as primary end-users, are at the receiving end of energy shortages and energy use-related pollution impacts. Women also suffer more due to their restricted mobility and lack of exposure to training and information. This is particularly evident in relation to warnings about, dangers of, and courses of actions to take in response to, natural calamities that may have been influenced or impacted by climate change. Furthermore, disasters, irrespective of their causes, generally accentuate discrimination, and women may not receive equal aid benefits that predominantly target male household heads.

In addition, conflict situations such as Afghanistan amplify the impacts of natural disasters such as severe winters and earthquakes, because the damage caused remains after the conflict is resolved. In these situations, resource-based conflicts are more pronounced due to lawlessness and rebel control of territories with natural resources such as water and grazing lands. These situations impact differently on men and women, often causing shifts in gender roles. In order to respond to climate crises in situations of conflict it is important to establish humanitarian gender responses from the context of climate change, have clear protocols on responding to environmental disasters in conflict settings and, most importantly, on how to prevent conflict under recurring effects of climate change.

And finally, gender perspectives on climate change, in terms of agriculture and food and water security in different ecosystems, should be considered while developing recommendations and strategies for the long-, medium- and short-term. Since the climate is changing rapidly, the policy approach should be flexible enough to adapt as new climate change-related information and knowledge becomes available. Women need to be meaningfully involved, not only as beneficiaries but also in the decision-making process especially in the areas of adaptation and mitigation. Understanding how the different social roles and economic status of men and women affect, and are affected differently by climate change will improve actions taken to reduce vulnerability and combat climate change, particularly in the developing world (IPCC, 2001).

1.4.2 Climate change and gender linkages in mitigation

Climate change mitigation is: “an anthropogenic intervention to reduce the sources of greenhouse gases or enhance their sinks.” It concentrates on either controlling the emissions of greenhouse gases or capturing and sequestering those emissions.2 Mitigation actions have largely focused on reduction of industrial greenhouse gas emissions, but also include the practice of energy efficiency and the application of renewable energy in commercial and residential sectors. The role of women in such climate change mitigation strategies has received little attention, as actions have been perceived to be either technical or scientific in nature and where including a gender perspective has not been a priority. However, as climate change is partly the result of human behavior and affects all people, mitigation strategies must consider the gendered patterns of energy use in order to be effective.

Women can play an important role in promoting mitigation measures such as:

- the practice of energy efficiency in households and community-based industries;
- renewable energy (including hydroelectric power) applications in rural households and communities;
- afforestation and reforestation activities; and
- waste minimization and recycling.

1.4.2.1 The role of women in mitigation actions

In many communities in developing countries gathering, transporting and purchasing household fuels is the responsibility of women. This becomes increasingly difficult with dwindling availability of food and biomass energy resources. Women without access to modern forms of energy are exposed to indoor air pollution and related health problems such as bronchitis, asthma and miscarriage. Access to non-polluting fuels that do not damage peoples’ health should be an important element of mitigation programmes. But it is essential that such considerations be integrated in an effective manner and with proper consultation regarding their effect on women. The policies, technological changes and instruments being proposed to mitigate carbon emissions must use and develop both gender-sensitive criteria and indicators to ensure their impacts do not bypass or negatively affect women.

However, there are concerns that as women switch to modern fuels, carbon dioxide (CO_2) emissions will increase and expose women to the price fluctuation and scarcity associated with resources such as oil. These alterations could further harm rural women who have little influence on foreign exchange imbalances, fossil fuel scarcity or excessive greenhouse gas emissions. This highlights why wealth is an important variable in consideration of the impact of gender on climate change. For example, a rural poor person in India emits only 100–300 kg of CO_2 per year, as compared to 2,000 kg emitted by an urban rich person in India, or 15,000 kg as the average emitted per capita per year in the United States of America (IPCC, 2001).

1.4.2.2 Potential gender entry points in mitigation activities

Gender can be integrated into climate change mitigation activities through clean development mechanisms (CDM). These enable entities in developing countries to implement carbon emission-reducing projects that earn certified emission reduction credits. They then can be traded, sold to, and used by industrialized countries to meet a portion of the latter's emission reduction commitments. CDM projects are not a panacea for solving climate-related problems but they potentially offer alternative approaches to integrating gender issues into climate change mitigation activities. There are a number of viable CDM development projects on waste management, afforestation, reforestation, energy efficiency and renewable energy, such as biofuels that could potentially benefit women to a larger degree, but these need to be promoted, scaled up and replicated for greater impact.

The role of, and benefits to, women in CDM projects can be highlighted in the project design documents of CDM projects. They should be recommended to designated national authorities as among the criteria for gauging the socioeconomic impacts of the proposed CDM projects when being reviewed and approved. CDM projects that are community-based offer indirect financial opportunities to women, but support has to be provided so that such opportunities are more accessible. CDM projects are largely developed by private companies where gender issues are usually neglected due to considerations of a financial, technical or logistical nature that result from lack of gender awareness. Therefore, it is important to integrate a gender perspective into climate change processes, instruments, mechanisms and developments so that it is included by all parties in all sectors.

1.4.2.3 Gender and climate change policy development

Gender mainstreaming is also needed in the ongoing policy dialogue processes, such as the Intergovernmental Panel on Climate Change (IPCC), the Conference of Parties (COP) and various discussions relating to vulnerability, adaptation and mitigation. Climate change bodies like the Subsidiary Body for Scientific and Technological Advice (SBSTA) and especially the Subsidiary Body for Implementation (SBI) should ensure that gender equality receives adequate attention. Countries involved in future COP meetings should conduct gender-specific discussions with balanced gender participation. UNFCCC should also ensure consideration of gender equality issues in the design of CDM projects, as well as UNFCCC-sponsored projects on technology transfer and capacity building and other related initiatives.

Gender considerations need to be incorporated into the National Adaptation Programmes of Action (NAPAs) activities of LDCs. Stakeholders in advocating and implementing actions to address vulnerability and adaptation to climate change issues need to be consulted on integrating gender equality issues. Furthermore the Global Environment Facility (GEF) and specialized UN agencies should begin to ensure gender mainstreaming into climate change mitigation. Governments and the private sector should be made responsible for integrating gender concerns into such climate change programmes, as they are major participants in the development process (http://www.undp.org/gef/about/gefsec.html).

1.5 Links Amongst Women, Gender, And Climate Changed Vulnerability

The empowerment of women is a related concept to gender equality. While gender explores the socioeconomic position of women and men in relation to each other, empowerment of women is necessary where women are in a disadvantaged position in comparison to men in terms of their socio-economic status. Indeed, the aim of empowering women is to close or narrow the existing gap between women and men by supporting women in various ways.

In many societies, socio-cultural norms and childcare responsibilities prevent women from seeking refuge or migrating to other places for working when a disaster hits. Osman-Elasha (2009) points out that it is situations like this that increase a women's burden in times of disaster, e.g. needing to travel longer distances to get drinking water and wood for fuel. Literature reviewed indicates that climate change will be an added stressor that will aggravate women's vulnerability; however, the example given seemingly is minor in comparison to common place 'women and gender' issues in Cambodia. Women, in many developing countries suffer gender inequalities with respect to human rights, political and economic status, land ownership, housing conditions, exposure to violence, education and health; most literature reviewed indicates that climate change is posed to exacerbate the effects of such issues… rather than add to the current list.

Poverty is also a driving force behind vulnerabilities to climate change for such limits the poor's ability to adapt appropriately; not mal adapt which is often the case. In times of disasters, e.g. flood, drought and agricultural failure, poor Cambodians often resort to selling assets; parents migrate in search of paid labor leaving children without care; to the more extremes like the trafficking of women and children. Vulnerability levels are high and the ability to cope with shocks is further compounded by household size, composition and underlying social vulnerabilities within the family. These underlying trends include land concentration, and declining access to common property resources such as fishery and forests which have traditionally served as social safety nets for the poor. However, as indicated in this review, the consequences of social and economic stresses are not the same for men and women, and not the same in the face of climate change.

The following discusses the aforementioned in a more specific context to women and gender respective of various climate change vulnerabilities both men and women, and Cambodia face. Subsections are integrated with actual climate change adaptation and adaptation research initiatives occurring in Cambodia – initiatives aimed at helping field-based practitioners understand better dimensions of women, gender, and climate change, and to help the reader contextualize the discourse presented in this literature review. Each subsection is also closed by a brief analysis and identifies areas for further research and analysis (Oxfarm America, 2010).

1.5.1 Women and gender dimensions towards vulnerabilities to natural disasters

Reducing vulnerability to disasters is paramount and such is supported systematically through a multitude of Disaster Risk Reduction (DRR) education initiates within schools. However, few studies indicate if this is an effective approach to reducing a women's vulnerability to climate change. Cannon (2007) stresses that addressing all elements of 'poverty' must go hand in hand with DRR educational initiatives for such to be successful. With education, young women can be empowered to demand better protection from social inequalities, and organize themselves to reduce their 'disaster risks', however, access to DRR education is not within reach for most rural Cambodian women or girls. Cannon (2007) points out that impoverished households will prioritize educational expenses for boys and young men, plus the need for poor households to withhold children from school for labor purposes are key factors in reducing the participation of children (especially girls) from poor families in educational opportunities.

Literature also notes that during extreme weather conditions, women tend to work more to secure household livelihoods and subsistence needs. In a country like Cambodia where drought and flood impacts are cyclical, this commonly leaves women with little time to access training and education, develop skills or earn income; all resources and capacities needed to lessen their vulnerability to natural disasters. This limited mobility, i.e. being tied to the household, places women disproportionately at risk to climate induced natural disasters (Cannon, T., 2007). Reacting to this context, there are recent efforts in Cambodia to reduce climate risks for women near their homes. Currently, the Joint Climate Change Initiative1 is supporting four (4) small Ecosystem Based Disaster Risk Reduction2 (EcoDRR) pilot projects throughout Cambodia, aimed at reducing climate risks specific to women; improving local health and nutrition status, reducing livelihood risks through diversification, and integrated approaches to ensuring soil stability through agroforestry. Efforts are tied to the formulation of commune DRR action plans that deeply consider women's needs in times of climate stress proactively; actions are linked to education and empowerment through the building of local organizations and gender focal persons using Rights Based Approaches to promote equitable multi-stakeholder cooperation.

Other DRR efforts that reflect a women and or gender focus can be attributed to organization such as Oxfam Great Britain, e.g. disaster relief for woman headed households in the form of replacing fishing gear and local transports losses associated with their livelihoods. It can be said that many forms of DRR efforts are taking place all over Cambodian, however, literature seemingly refers to 'gender' as a consideration within the DRR training processes, and not a theme or focused topic, i.e. often 'gender' is centered on a women's role to reduce the risk of children contracting dengue and malaria and to a lesser degree on how DRR relates to Human Rights (ISDR and WB, 2009).

1.5.2 Women and gender dimensions within the agriculture and fisheries sectors

Cambodian women are the most economically active in Asia and while gender attitudes are changing, significant gender inequalities continue to persist. Cambodia has the lowest levels of gender equity in Asia as measured by the Gender-related Development Index (0.593 in 2009), and a Gender Empowerment Index of 0.377 in 2008, due to poor access to health and education services, productive employment opportunities and land ownership (UN-DAF, 2010, and UNDP, 2010). The same report, and others, point to climate change vulnerability of both the agriculture and fisheries sector and a heighten level of risk for women's livelihoods as they have a significant involvement in post-harvest activities (MAFF and CBNRM LI, 2008). This vulnerability is further heighten for women in agriculture for they are often unpaid family workers with little options for coping with disasters. Even for women headed household's active in both subsistence and waged agricultural activities; when 'disaster' hits the sector, prevalent low levels of literacy and education limits their options in the form of livelihood alternatives assessable to them.

The aforementioned are data driven statements combined to conjecture stated within the literature. However, for Cambodia, what is missing from the literature reviewed is an expressed understanding of gender dimensions in both subsistence and wage agriculture and fisheries. Chan sothea et. al. (2007) states that this would require detailed knowledge of family operations… that which goes beyond statistics that are widely available. For example, household farming operations on one hand generate cash for daily consumption, i.e. subsistence fishers and backyard farmers; on the other hand some activities are spread out over time, i.e. rice and livestock farmers. And in many cases, families are involved in the aforementioned at one time, and other livelihood activities throughout the year. From literature reviewed, often reported is data in the form of segregated numbers; thorough analysis of the interconnections between livelihood activities and dimensions of vulnerability is absent. Absent also is analysis geared towards sector production declines and the impact this has on the post-production activities of paid women workers. Women do have on-farm and off-farm productive roles (some paid, some not), even that between the two sectors throughout a year. Hence, are declines in economic productivity equitable respective of the productive roles for both men and women in times of climate stressed conditions? If so, how, if not, why? Do declines in sector activity come at the same time (agriculture and fisheries) given specific climatic conditions or is it possible that stresses in one sector are offset by favorable conditions in another. This idea has been presented in the literate cited, but no definitive experiences have been well defined. Outlined in very recent research conducted by UNEP-AIT in the village of Otasek, O Otnhaheng Commune, in the District of Prey Noub, Sihanouk Province, it was clear that both agricultural and fisheries sectors can decline at the same time via climatic stresses; exacerbated by poor social and governance contexts.

Noted by researchers, coinciding climate induced conditions of drought, heat, and pest infestations dramatically impacts agricultural production; driving a shift to fisheries and NTFP based livelihoods. Intense extractive activities at these times, without proper resource management in place, actions have decimated the natural resource base. As both men and women headed households are involved in these 'extractive process', clear is that men have fared better due to better access to the resource base itself, physically, and via access to technological assets. For women headed household, access to the resource base is difficult respective of obtaining assets to fish, and time available outside of their reproductive roles to do so – adapting out of necessity, their children are involved in the fisheries at a very young age. Villagers have noted that in the past, moving from one ecosystem to the next worked well for them, until outside interests began to exploit their natural resources illegally. Hence, climate stresses can shift livelihood strategies;

however, benefits to be derived are influenced by a multitude of social factors – not just gender differences (Mak, S. 2008).

1.5.3 Women and gender dimensions towards health

Women represent a high percentage of poor communities dependent on local natural resources for their livelihood, particularly in rural areas where they shoulder the major responsibility for household water supply, energy for cooking and heating, and family food security. Gender dimensions of this have been covered in other sections of this review, however, there is still a need to bring forth important dimensions respective of climate change and health, particularly that of water borne diseases and why women tend to be vulnerable. This importance is captured in UNFCCC (2007) reports indicating that climate change threatens to reverse progress in fighting diseases of poverty, e.g. malaria, dengue, even mental health.

Reported by Oxfam (2009), the Cambodian Ministry of Environment has projected significant increases in malaria incidents under changing climatic conditions in the area of 16%. The Ministry contributes projected rises as a result of natural disasters upsetting already fragile ecosystems further. Currently, clear is that natural disasters have coincided with increased reports of contagious diseases such as malaria, and other physical and psychological disorders; but there are discrepancies in the literature respective of dengue fever. The UNFCCC (2007) has stated that so far no connection has been established between climate change and the exceptionally high number of dengue cases being seen in Asia… however, there seems little doubt that rising temperatures and unseasonably high rainfall have a role in this.

Neither of the aforementioned reports have expressed gender dimension to impacts or projections. But, Haigh, C., and B., Vallely (2010) have expressed that there are gender dimensions indirectly that need further investigation, understanding and discourse. Through testimonies, they report incidents of widows and orphans having real difficulty in adapting to climate change for they are weak and easily get ill. Also noted is that during incidents of disaster, food prices rise, and this tends to lead to a reduction in the quality or quantity of the food rural poor families are able to purchase, with women most likely to make sacrifices. From the ground, Mak, S. (2008) states that ‘women’ often borrow money from informal money lenders to make up for food shortages and to pay for health treatments; paying interests of 10% per month due to a lack of assets to borrow from cheaper formal lending services… in turn purchasing the minimal amount of food as necessary - resulting in physical weakness and falling ill to disease such typhoid, dengue, and fever… again consuming already stressed levels of income – starting the borrowing cycle over.

The resulting poor nutritional status of women also increases their vulnerability to disasters, and makes the physically strenuous tasks of water and fuel collection more difficult. Haigh, C., and B., Vallely (2010) go on to connect ‘food hierarchies’ as a source of protein deficiency for women, and that as climate change may impact fresh water systems and fish populations; this will have a disproportionate effect on women’s nutrition and health. Observations by Osman-Elasha, B., (2009), MAFF-CBNRM LI (2008) and Sun, V., and T., Kouk (2002) take Haigh, C., and B., Vallely (2010) state collectively that the disproportionate impact on women’s nutrition and health can be contributed to their limited access to and control over ecosystem and development services; further stating that women have negligible participation in decision-making and are not involved in the distribution of environmental management benefits. Consequently, women are less able to confront vulnerabilities associated with climate change. Hence, again there is a need to distinguish between vulnerabilities associated with poor sectoral responses to the needs of the rural poor and the causes of women's vulnerabilities – are they because of climate variability, because of tradition/ cultural barriers, because of gender insensitivities, or how development service agents go about creating awareness, assistance, and feedback amongst the development community for more responsive actions. Hence, needed is analysis into where true barriers are to improving women's health, i.e. preventing malaria and dengue is not a technical matter. On the other hand, more accessible women centered technologies to home food production are still needed to resolve family based nutrition deficiencies.

1.5.4 Gender and decision-making at household, community and national levels

The National Biodiversity Strategies and Action Plans (NBSAP) report (Sasvari, et., al., 2010) indicates the importance of equitable participation in decision-making, "Experience has shown that equitable gender representation, involvement and participation of local communities and concerned stakeholders is a prerequisite for successful conservation and sustainable resource use initiatives". The report goes on to indicate the importance of women in decision-making processes to ensure the appropriate management of not just household resources, but also community resources to improve conservation approaches towards biodiversity and resilience to climate change. Accordingly, literature often refers to the importance of gender balanced decision-making; and as often, notes that women have negligible capacities to participate in decision-making processes respective of natural resource use (Osman-Elasha, B., 2009). Information distributed through Care (2010) expresses that this inequity in decision-making is deeply rooted in Cambodian society from an early stage; pointing out that adolescent girls are an increasingly marginalized group. Stated is that only 32% have completed grade six, compared to 67% of boys, and that young women are seen as less important due to their lower status within the community.

A CDRI report by Somatra et., al., (2008) discusses theories around participation - its evolution, advantages and loopholes, and some arguments related to the concept and applicability of participation in the Cambodian context – not specifically from the point of gender but the importance of local participation as a whole. Looking at irrigation water governance, this report discusses what it means for people to participate in making use of water from an irrigation scheme and the main factors behind their decision to do so. The article also discusses people's participation in operational decision making. The report concludes that people's participation in the use of irrigation water is largely driven by economic reasons; how much they are willing to make use of water is determined by how much profit they see in doing so, but their decision to do so is constrained by their limited resources, equipment, finance, and sometimes labour. As for participation in operational decision making, people participate more actively now, but this still has limited influence on operational policy changes as farmers are afraid to act against the majority.

CDRI (2008) contributes the aforementioned discourse to 'participation' as a lack of national development services being responsive to local needs, thus resulting in disproportionate social and environmental impacts. Furthermore, CDRI (2008) goes on to state that unlike large-scale schemes, a small-scale approach is usually more decentralized, and better enables women and men to communicate their needs to local officials and service providers. Noted is that principles of solidarity, without reference to women or gender specifically, encourage decision making at the lowest appropriate level in the planning and implementation of water projects. Sun, V., and T., Kouk (2002) further add to this discourse, but in the context of forestry resource management decision making. Indicated is that woman are responsible for 67% of NTFP extractive activities, yet their involvement in local level decision making is negligible. Understood by women are their rights, but not in the context of gender. Traditional attitudes towards women's work, lower education attainment and the lack of peer support – women to women – pose serious barriers to participating in planning, implementation, and decision making process locally.

Form the Heinrich Böll Foundation (HBF, 2009), Cambodian women working in NGOs generally are fully familiar with their foreign promoters' gender discourse and that rural women struggle with harsh circumstances. Fundamental to their struggle is the lack of access to education, illiteracy, economic dependency, and hierarchical gender relations founded on traditional role stereotypes. The latter problem contributes to excluding women from active participation in decision making and political processes. HBF (2009) goes on to state that even in those cases where women hold leading roles in local communities or organizations; they are heavily dependent on men in the process of laying claim to their rights. In the climate change context, the selling off of natural resources and the social and ecological consequences of this form of economic development model only caters to the interests of a small political and economic elite… negative impacts are borne especially by women.

Noted throughout this literature review has been the limited space government and society allows women in household and institutional space to influence decisions; often not seen is enthusiasm by government and NGOs to take on women empowerment activities in rural Cambodia – and even less enthusiasm by government to give a voice to NGOs and local level institutions battling for accountability and sustainability. However, there have been some movements forward. The recently established Commune Committees for Women and Children (CCWC), the proposed provincial and district Women's and Children's Consultative Committees (WCCCs) and Commune Committees for Disaster Management (CCDM) have been delegated the responsibility of addressing social and 'climate induced' disaster management issues. However, they are underfunded and lack support from the District level. Hence, the potential of these committees to address gender imbalance in local participation in the planning, budgeting and delivery of development services becomes highly questionable. As a reality, gender representatives at the local level have contented themselves with collecting health and hygiene statistics, working on improvements to sanitary facilities, and to a far lesser degree, building gender sensitivity and equity within their target areas (HBF, 2009).

As women remain greatly under-represented in the executive branches of government (UN DAF, 2010), this only ensures that obtaining gender equity in 'development' and 'climate change responses from the aforementioned councils may prove to be a challenge. Expressed in the literature by HBF (2009) and others, is that the Cambodian government, even NGOs, have simply taken over 'gender' terminology merely as a development policy slogan, empty of any professional or personal confrontation with the related ideas. A wider political understanding is still absent in many cases and further analysis into why this is, is desperately needed. What actually promotes meaningful participation; can/ do incentives devised breach cultural or traditional stereotypes without negative consequences? Two questions that need further thinking and action.

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ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia

MODULE II:

CLIMATE CHANGE MITIGATION

December, 2021

Introduction to the Training Manual

Background and Aims of Training: Climate change is one of the biggest long-term risks to global development. This makes choices and investment made in climate change mitigation vital for ensuring sustainable and inclusive growth. Adaptation and Mitigation is the most comprehensive and up-to-date scientific, technical and economic assessment of options to mitigate climate change. This training manual supported a 4-day training on **"Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia"**. The development of a training manual and the training of trainer program on climate change adaptation and mitigation that are the critical to achieving the objectives of the training in building capacity to adapt to climate change and climate variability in Cambodia.

Purpose of this Training Manual: This training manual seeks to provide knowledge of and training in Climate Change Adaptation and Mitigation. In this context the trainee will learn the definition of adaptation, mitigation, important of climate change adaptation, vulnerability and adaptation assessment, climate change adaptation action like NAPA, concept of NAPA, NAPA implementation, NAP. This training manual also provide the definition and scope of mitigation, greenhouse gas definition, linkage between mitigation and adaptation, cost effective mitigation, mitigation opportunity and potential by sector, land use, land use change and forestry and other activities and program the help people to mitigate with climate change as well as.

How the training materiel was developed: There are many sources for developing this manual. Internet is the major source including www.who.org and www.oaresciences.org which is the international Journals for best matching literature review. However, since the scope of this manual is mainly demonstrate in the context of Cambodia; it is very important to access the documents from IPCC, MoE and other reports for documentation and also others research as well.

How to use this manual: This manual can be used for additional documentation for raising-up general knowledge in climate change adaptation and mitigation. It does really benefit for those who want to know about adaptation and mitigation to climate change and other researches. Before reading this manual please doesn't forget to go through with this Introduction.

Module II: Climate Change Adaptation and Mitigation

The purpose of this training module is to provide trainees in national and sub-national of governmental institutions with KSA (Knowledge, Skills, and Attitude) on climate change mitigation.

Target Group:

Lecturers, researchers, and staffs in agricultural universities/institutions in Cambodia who interest on climate change.

Learning Outcome:

At the end of the module, the participants will be able to understand climate change mitigation

Learning Objectives:

- To understand the climate change mitigation

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ABBREVIATIONS

ADB	Asian Development Bank
AEZ	Agro-ecological zones
ASEAN	Association of Southeast Asian Nations
CC	Climate Change
CCA	Climate Change Adaptation
CCCA	Cambodia Climate Change Alliance
CCCO	Cambodian Climate Change Office
CCCSP	Cambodia Climate Change Strategic Plan
CCM	Climate Change Mitigation
EPA	United States Environmental Protection Agency
GEF	Global Environment Facility
IPCC	Intergovernmental Panel for Climate Change
LDCEG	Least Developed Countries Expert Group
MAFF	Ministry of Agriculture, Forestry and Fisheries
MOE	Ministry of Environment
MRC	Mekong River Commission
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action to Climate Change
NCDM	National Committee for Disaster Management
RGC	Royal Government of Cambodia
SRES	Special Report on Emissions Scenarios
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USGCP	United States Global Change Research Program
WB	World Bank
WFP	United Nations World Food Programme

CLIMATE CHANGE MITIGATION

2.1. Introduction to climate change mitigation

2.1.1. Definition and scope of mitigation

2.1.1.1. Definition

Mitigation refer to technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks (IPCC, 2007).

Mitigation is a human intervention to reduce the sources of greenhouse gases (GHG) emission (abatement) or enhance the sinks (Sequestration). Mitigation, together with adaptation to climate change, contributes to the objective expressed in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC). In the context of the UNFCCC, a **mitigation assessment** is a national-level analysis of the various technologies and practices that have the capacity to mitigate climate change (IPCC, 2014).

2.1.1.2. Scope of Mitigation

A mitigation assessment may include a variety of areas. These include energy demand and supply, forestry, agriculture, rangelands, and waste management. Ideally, an assessment should include analysis of the impact of mitigation options (particularly in energy sector) on the macro-economy. Countries should structure their assessment to address the topics of most importance, taking into consideration the resources available to perform the study. A mitigation assessment should include some consideration of policies and programs that can encourage adoption of mitigation technologies and practices. More detailed evaluation of particular policy/program options could follow an initial assessment.

Countries should design their assessments to satisfy the needs of the various possible users or stakeholders. The primary users of the assessment are likely to be policy decision-makers who are responsible for evaluating and designing mitigation policies. The country's scientific community is likely to benefit from participation in the assessment process, and also from the compilation of data and access to new modes, which will also be useful for other type of analysis. Other potential in-country users include the NGO community. In addition, the output of each assessment may be shared with interest groups in other countries, and regional and international organization.

2.1.2. Greenhouse gas mitigation

Climate change is one of the most complex and challenging environmental problems the world is facing. The complexities include the wide range of greenhouse gas (GHG) emissions by source and removal by sinks. Total anthropogenic GHG emissions have continued to increase over 1970 to 2010 with larger absolute decadal increases toward the end of this period (high confidence). Despite a growing number of climate change mitigation policies, annual GHG emissions grew on average by 1.0 gigatonne carbon dioxide equivalent (GtCO2eq) (2.2%) per year from 2000 to 2010 compared to 0.4 GtCO2eq (1.3%) per year from 1970 to 2000.Total anthropogenic GHG emissions were the highest in human history from 2000 to 2010 and reached 49 (±4.5) $GtCO_2eq/yr$ in 2010. The global economic crisis 2007/2008 only temporarily reduced emissions (IPCC, 2014).

In total anthropogenic GHG emissions in 2010, CO_2 emissions from fossil fuel combustion and industrial remains the major anthropogenic GHG accounting for 76% (high confidence) (38 ± 3.8$GtCO_2eq/yr$) of total anthropogenic GHG emissions 16% (7.8±1.6 $GtCO_2eq/yr$) come from methane (CH_4), 6.2% (3.1±1.9$GtCO_2e/yr$) from nitrous oxide (N_2O), and 2.0% (1.0 ± 0.2$GtCO_2eq/yr$) from fluorinated gases. Annual anthropogenic GHG emissions have increased by 10 $GtCO_2eq$ between 2000 and 2010, with this increase directly coming from energy supply (47%), industry (30%), transport (11%) and buildings (3%) sectors (medium confidence). Accounting for indirect emissions raises the contributions of the buildings and industry sectors (high confidence) (IPCC, 2014).

Under the UNFCCC, developed countries (Annex 1 Countries) agreed to reduce GHG emissions from the source sides and increase GHG uptake by sinks, while developing countries could participate in reducing their emissions or increasing the uptake on a voluntary basis using national, multilateral or bilateral funds. Mitigation scenarios in which it is likely that the temperature change caused by anthropogenic GHG emissions. Scenarios reaching atmospheric concentration levels of about 450 ppm CO_2eq by 2100 (IPCC, 2014) (consistent with a likely chance to keep temperature change below 2°C relative to pre-industrial levels) include substantial cuts in anthropogenic GHG emissions by mid-century through large-scale changes in energy systems and potentially land use (high confidence).

2.1.3. Linkage between mitigation and adaptation

When most local and tribal governments think of climate protection, they think first of mitigation -actions to reduce the amount of human-caused greenhouse gas emissions, to avoid further disruptions to the Earth's atmosphere. But while effective mitigation action is crucial, it is not the only aspect of climate protection that local governments can engage in. Adaptation is the other half of comprehensive climate protection. Adaptation involves recognizing impacts of climate change that are already occurring and will continue into the future, and planning ahead to maximize the positive aspects of these impacts while protecting lives, health, property and ecosystems from the negative ones. Adaptation and mitigation can be complementary, substitutable or independent of each other.

The difference between mitigation and adaptation

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007) defines mitigation and adaptation as:

Mitigation: Implementing policies to reduce greenhouse gas emissions and enhance sinks.

Adaptation: Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Another way to think about it is to consider mitigation as activities to protect nature from society, while adaptation constitutes ways of protecting society from nature.

Energy

Mitigation	Adaptation
Reduce emissions by expanding use of renewable sources	Reduce vulnerability to widespread power grid outages by encouraging distributed generation from multiple renewable sources (solar, wind, biogas, landfill methane, etc.)
Reduce emission by improving efficiency of energy and water delivery systems	Reduce potential for grid overload and failure by decreasing demand.

Green Building Strategies

Mitigation	Adaptation
Reduce emission by curbing energy use through greater efficiency	Lower energy use will create less demand on the grid during extreme events such as heat waves, decreasing the likelihood of blackouts
Adopt or encourage LEED building standards for commercial, residential, retrofit and municipal projects	Building standards could include greater resistance to high winds, flooding, etc.
Implement a weatherization program	Better insulated buildings that rely on day lighting and natural ventilation will be more functional and comfortable during power disruptions, reducing the potential for heat-or cold-related illness and death during power supply disruptions.

Food Production and Distribution

Mitigation	Adaptation
Reduce emission by encouraging local food production through local agriculture, community gardening, etc. to decrease the number of miles food must be transported	Reduce reliance on centralized food system where commodity production is concentrated in a few locations the may be vulnerable to climate disruptions such as storm damage, pest outbreaks, etc.

Forestry and Open Space

Mitigation	Adaptation
Increase carbon sequestration by promoting healthy forests (including urban forestry and natural open space	Reduce vulnerability to flooding by promoting functional watersheds, including healthy forests and open space
	Increase habitat available to climate-stressed species by protecting open space
	Counteract urban heat island impact by planting trees to provide shade and cooling

Smart Growth and Transportation Strategies

Mitigation	Adaptation
Reduce emissions by decreasing vehicle miles traveled through compact development	Improve delivery of disaster assistance and reduce costs of rebuilding
Promote high-density and in-fill development through zoning policies	Reduce area that emergency personnel must cover, making delivery of disaster assistance more efficient
Institute growth boundaries , ordinances or programs to limit suburban sprawl	
Give incentives and bonuses for development in existing downtown areas and areas near public transit	Makes evacuation easier and more efficient

Discourage sprawl through impact, facility, mitigation, and permit fees	Reduces number of miles and costs of repairing or replacing infrastructure (i.e. roads, bridges, electrical and sewer lines) when climate-related disaster strikes; also reduces fragmentation of ecosystems, allowing them to function more effectively.

Water	
Mitigation	**Adaptation**
Reduce emissions by reducing water use (less energy required for treating and transporting water	Conserve water so more in available during more frequent and severe droughts

2.1.4. Current status of CDM in Cambodia

The Royal Government of Cambodia (RGC) is strongly committed to the Kyoto Protocol and sees CDM as an opportunity to achieve national sustainable development and poverty reduction objectives, while at the same time reducing greenhouse gases emissions. Currently the RGC is working to establish institutional and human capability to fully utilize CDM and contribute both towards sustainable development of Cambodia and GHG emission reduction in the world.

On 15 July 2003, the RGC appointed the Ministry of Environment (MoE) as the Interim Designated National Authority (DNA) for CDM (Government Decision No. 01). To date MoE is the national implementing agency for a number of projects that aim to generate broad understanding and develop institutional and human capacity to fully participate as equal partner with developed countries in the formulation and implementation of potential Clean Development Mechanism projects in Cambodia.

The Cambodian DNA is responsible for assessing proposed CDM projects against national sustainable development criteria and is authorized to provide written approval for proposed CDM projects in accordance with these criteria. Cambodia uses a sustainable development matrix as a tool for assessing the contribution of CDM projects in four aspects of sustainable development: economic, social, environmental and technology transfer.

Benefits from CDM projects

CDM can help investors access additional finances for projects that reduce GHG emissions by selling carbon to buyers in developed countries. It will also assist developing countries, like Cambodia, in accessing the opportunity to achieve sustainable development goals, through transferring of technologies and financial resources, poverty alleviation via income and employment generation and improvement of local environment.

Project types attractive in Cambodia

Renewable energy, energy efficiency, landfill gas capture, afforestation and reforestation have been identified as potential CDM projects in Cambodia. Small-scale CDM projects eligible for simplified methodologies are considered to be the most appropriate for the Cambodian context.

Where can project developers find support for CDM

The Cambodian Climate Change Office (CCCO) was established in July 2003. The Office acts as the DNA Secretariat and can assist all project developers in CDM-related matters including:

- Provide advice on how to prepare a good CDM project;
- Introduce potential CER buyers to project developers.

Potential CDM project

Cambodia, leader among least developed countries when it comes to CDM awareness and DNA capacity, now has several CDM project ideas in its pipeline. Due to the current low electrification rates and efficiency of the national power system, Cambodia has made efforts to implement a sustainable energy efficiency program aimed at meeting its domestic energy needs. Therefore, the CDM project pipeline can be complimentary to help the Government achieve these goals and to improve the well-being of local residents.

Japanese project developer Mitsubishi Securities has completed a PDD on a 1.5 MW rice husk power plant generating 45,000 CERs annually. The PDD was now posted in the UNFCCC's website for review and comment. The estimate of Greenhouse Gas reduction up to a period of 7 years is 320 KT of CO2eq.

A Letter of Endorsement has been signed for a Japanese investor on methane capture from pig farms to produce electricity. The electricity produced from the plant may replace EDC grid electricity which emits CO2 into the atmosphere from the heavy fuel oil and diesel power plants.

An afforestation project of 7,900 ha is envisaged by Japanese company Marubeni at northeastern Mondulkiri Province and will sequester 2.9 Mt of CO2eq for the period of 30 years. In addition, Marubeni Company has developed a PDD on renewable energy project using wind and solar power with the estimated total CO2 emission reductions of 57,939 t CO2eq during the crediting period of 21 years.

An Italian company, Actelios, has developed a Project Idea Note for a landfill gas collection project in Stung Meanchey, Phnom Penh. This 90,000 CERs p.a. landfill gas collection project has received formal support from the Ministry of Environment of Cambodia. The company may also consider using captured methane for power generation in the future. The estimated GHG abated for the period of 10 years is 858,000 t CO2eq.

Investing in CDM in Cambodia

All proposed CDM projects must comply with the Law on Investment in the Kingdom of Cambodia, promulgated in 1994 and amended in 2003, which provides the institutional and legal basis for foreign investments in Cambodia. The Council for the Development of Cambodia (CDC) is the governmental body responsible for the development and management of Foreign Direct Investment (FDI). CDC is an executive agency responsible for defining investment strategies and accepting or rejecting investment proposals. There are some incentives available.

Depending on the nature and size of their activities, CDM projects undertaken in Cambodia may be required by law to undertake an Environmental Impact Assessment (EIA). Potential CDM projects requiring an EIA include, but are not limited to: power plants with installed capacity of 5

MW and higher, hydropower plants with installed capacity of 1 MW and higher, agriculture and agro-industrial land of 10,000 ha and higher.

CDM afforestation and reforestation projects must comply with the Forestry Law, which aims to ensure the sustainable management of forests. CDM energy projects producing electricity must comply with the Electricity Law, which governs the operations of the power industry.

Table 1 List of registered CDM projects

Title	Type of Project	Emission Reductions ($t\text{-}CO_2/y$)	Project Participants (Host Country)
Angkor Bio Cogen Rice Husk Power Project	Biomass	51,610	Angkor Bio Cogen Co., Ltd.
T.TY. Cambodia Biogas Project	Biogas	50.036	T.T.Y Agricultural Plant Development and IMEX Co., Ltd; Carbon Bridge Pte Ltd.
Methance fired power generation plant in Samrong Thom Animal Husbandry	Biogas	5,593	Samrong Thom Animal Husbandry
Kampot Cement Waste Heat Power Generation Project (KCC-WHG)	Waste heat/gas utilisation	17,107	Kampot Cement Campany Co., Ltd.
Biogas Project at MH Boi-ethanol Distillery, Cambodia	Biogas	58,146	MH Bio-Energy Co., Ltd.
W2E Siang Phong Biogas Project Cambodia	Biogas	26,592	W2E Siang Phong Co., Ltd.
Lower Stung Russei Chrum Hydro-Electric Project	Hydro	701,199	China Huadian Lower Stung Russei Chrum Hydro-Electric Project (Cambodia) Co., Ltd
Cambodia Stung Atay Hydropower Project	Hydro	266,472	C.H.D (Cambodia) Hydorpower
Stung Tatay Hydroelectric Project	Hydro	563,074	Cambodia Tatay Hydropower Ltd.
Kamchay Hydroelectric BOT Project	Hydro	281,348	Sinohydro Kamchay Hydroelectric Project Co., Ltd.

Source: IGES CDM Programmes of Activities Database 2014

Investment in such projects can lead to:

- Transfer of environmentally friendly technology and financial resources;
- Sustainable production and use of energy;
- Increased energy efficiency & conservation;
- Poverty alleviation through income and employment generation;
- Local environmental and social benefits; and
- Biodiversity conservation and ecosystem rehabilitation.

There are many developing countries and many potential CDM projects which will compete to attract CDM investors. Cambodia is currently using the Capacity Development for CDM (CD4CDM) project to build its capacity to attract CDM investors to Cambodia.

2.2. Cost effect of climate change mitigation

2.2.1. The cost of climate change mitigation

The United Nations Framework Convention on Climate Change makes clear that cost-effectiveness is an important criterion to be used (among others) in formulating and implementing climate policies. As stated in Article 3.3 of the convention "taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure that global benefits at the lowest possible cost (UNFCC, 1992)".

The impacts of climate policy can be defined as the changes that policies cause relative to some "business-as usual" or "baseline" situation. A baseline is a scenario of how the global or regional environments, depending on the study, will evolve over time (often over 100 years or more for baselines used in climate policy studies) in the absence of climate policy intervention. Thus, a baseline is typically built upon assumptions about future population growth, economic output, and resource and technology availability, as well as upon assumptions about future non-climate environmental policies, like controls on sulphur dioxide emissions. Changes from these baselines are frequently put into categories of "benefits" and "costs". The benefits included in the calculus are estimated from avoided climate damages and other ancillary benefits that would have otherwise occurred if mitigation policies had not been introduced. The costs for mitigation and other side effects that result are estimated from economic sacrifices that might be required to mitigate climate change.

Climate change would be a relatively simple problem to overcome if it could be avoided without sacrifice and if the means to effect this avoidance were recognized widely. At present, however, there are concerns about the sacrifices that avoiding climate change might involve. Fundamental challenge in mitigation policy analysis is thus to discern how climate change can be avoided at a minimal cost or sacrifice.

Opportunity cost (the value of a sacrificed opportunity) constitutes a basis upon which estimates of economic cost are constructed. The extent of the costs of mitigating climate change is, from an economic perspective, measured in terms of the value of other opportunities that must be forgone (for example, the opportunity to enjoy low prices for domestic heating or other energy services). It follows that economic costs can be different when they are viewed from different perspectives. Costs of mitigation incurred by a regulated sector are, for example, generally different from economy-wide costs. Costs are sometimes measured in currency units, but they are sometimes also measured against other metrics. In all cases, though, the underlying element of cost is the sacrifice of opportunities, goods, or services; and this element is often quite different from the overt financial outlay involved. In measuring opportunity costs, more specifically, economic analyses generally take personal preferences, social and legal institutions, and cultural values as given. Yet climate policies can affect (positively or negatively) the functioning of institutions. They can alter the ways in which people relate to each other; and they can influence individuals' attitudes, values, or preferences. Taking these impacts into account can alter the cost assessment. Moreover, while economic analyses (including standard benefit–cost analyses) tend to measure costs by adding up individuals' valuations of their forgone opportunities; other approaches to cost can be defined in terms that are not simple aggregations of individual measures. As discussed below, equitable policy making brings attention to the distribution of costs as well as to their aggregate levels. Both theoretical and modeling studies have helped to reveal the types of policies that might achieve given targets at the lowest cost. Moreover, as indicated below, models have identified certain circumstances in which at least some reductions in GHGs might be achieved at no cost. Most model-based studies indicate that the first units of abatement are fairly inexpensive; “low-hanging fruit” is easily picked. However, most studies show that additional units of abatement require more extensive changes and involve significantly higher costs. Thus, to lower the original concentration target is projected to result in a more than proportional increase in costs.

The cost of mitigation depends not only upon the cumulative emissions reductions required over the next century, but on the timing of these emissions reductions as well. In addition, deferring the bulk of abatement effort to the future allows more discounting of abatement costs. However, other studies show potential cost advantages in concentrating more abatement towards the near term. These studies argue, in particular, that near-term abatement helps generate cost-effective “learning-by-doing”, by accelerating the development of new technologies that can reduce future abatement costs. These findings are not necessarily contradictory. By introducing mitigation efforts in the near term, the process of learning-by-doing is initiated. At the same time, by increasing over time the stringency of policies (that is, the extent of abatement), nations can avoid premature capital stock turnover and exploit the cost savings from future technological advances. It is worth emphasizing that abatement policies can proceed in the near term even when abatement efforts are significantly deferred to the future. The near-term introduction of policies helps to stimulate efforts to bring about new technologies, which is crucial to enable future abatement to be achieved at lower cost. These include traditional regulatory mechanisms such as technology mandates and performance standards. They also include “market-based” instruments such as carbon taxes, energy taxes, tradable emissions permits, and subsidies to clean technologies. They also include various voluntary agreements between industries and regulators. A group of countries that wishes to limit its collective GHG emissions can agree to implement some of these policies in a coordinated fashion. Any given target is achieved at the lowest cost when the incremental cost of emissions reduction (abatement) is the same across all emitters. It follows that cost-effective emissions reductions hold the promise of allowing larger emissions reductions from any allocation of resources while market-based instruments such as carbon taxes and tradable carbon permits have potential cost advantages, the extent to which these potential advantages are actually realized depends on whether the policy generates revenues and whether these revenues are “recycled” in the form of cuts in existing taxes. Revenue recycling is important to the costs of a carbon tax, for example. When the revenues from the carbon tax finance reductions in the rates of pre-existing taxes, some of the distortionary cost of these prior taxes can be avoided; and so the cost of mitigation is reduced. The issue of revenue recycling applies also to policies that would reduce CO2 through carbon permits or “caps”. Revenues could be recycled through cuts in existing taxes if CO2 permits are auctioned. In contrast, if the permits are distributed freely, then no revenue is collected and there is no possibility of revenue recycling. Thus, auctioning the permits has a significant potential cost advantage over free allocation.

It is also important to keep in mind that aggregate costs are not the only useful consideration in evaluating alternative policy instruments from the cost-effectiveness perspective. The distribution of these costs across businesses, regions, and individuals is important as well. Moreover, other important evaluation criteria, including administrative and political feasibility, can play a role in determining exactly how and why mitigation initiatives might emerge.

The theoretical and modeling literature also reveals that international policy co-ordination through "flexibility mechanisms" offers enormous opportunities to achieve given reductions in GHG emissions at relatively lower cost. In principle, coordinated policies can be designed so that cost-effectiveness is improved on a global scale. Most studies of national or global mitigation costs focus on CO2 from fossil energy alone, but some recent studies consider other GHGs as well. Emissions of several of the GHGs (such as methane and nitrous oxide) from some sources can, in addition, be very difficult to monitor. This practical complication raises the potential cost of mitigation over the short- to medium-term, because it highlights the need to improve the methods used to monitor these emissions.

2.2.2. The role of Technology

The time horizon for climate change is long. The climate impacts of decisions made in the next decade or two will be felt over the next century and beyond. As a result, technology and, more specifically, improvements in the rate and direction of technological change, will play a very important role. The development and diffusion of new technologies is perhaps the most robust and effective way to reduce GHG emissions. Three aspects of technology can be distinguished: invention (the development, perhaps in a laboratory, of a new production method, product, or service), innovation (the bringing of new inventions to the market), and diffusion (the gradual adoption of new processes or products by firms and individuals). The studies show that hundreds of recently invented technologies can improve energy efficiency and thus reduce energy and associated GHG emissions. These technologies can yield more energy-efficient buildings and appliances and equipment used in them. There are, however, significant barriers to their innovation and diffusion. We can classify these barriers and provides a framework for understanding their connections with one another. Some new low-carbon emission technologies are not adopted because their cost and performance characteristics make them unattractive relative to existing technologies. To be adopted, these technologies require tax advantages, cost subsidies, or additional cost-reducing or performance-enhancing research and development. Other technologies could be adopted more rapidly if market failures and other socioeconomic constraints are reduced. Market failures refer to situations in which the price system does not allocate resources efficiently (Opschoor, 1997).

2.2.3. The role of Uncertainty

The uncertainties that surround climate change are vast. The connections between emissions of GHGs and climate change are not fully understood. In addition, uncertainty distorts our understanding of the impacts of climate change and the value of those impacts to humans. These uncertainties depend on scale, and become larger across the spectrum from "average" impacts across broadly defined geographical areas to specific impacts felt at a more local level. The uncertainties that surround climate change bear on the issue of whether mitigation policies are justified. Some analysts might conclude that these uncertainties justify the postponement of significant mitigation efforts–particularly those that involve economic sacrifices–on the grounds that not enough is yet known about the problem. However, uncertainty also introduces the risk that the opposite will occur. There is a significant possibility that scientific investigations will ultimately reveal that the continued accumulation of GHGs will have severe consequences for climate and substantial associated impacts. Indeed, if postponing mitigation efforts allow irreversible climate impacts to occur, then no future efforts, at any cost, can undo the resultant damage. The risks of premature (or unnecessary) action should therefore be compared with the risks of failing to take action that later proves warranted. As stated in Article 3.3 of the Framework Convention "…The parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects" (UNFCCC, 1992). It is generally sensible for a person to purchase fire insurance on his or her house (despite the likelihood a fire will never occur). Likewise, it is rational for nations to insure against potentially serious damages from climate change, despite the significant chance that the most serious scenarios will not materialize. The term precautionary principle has been employed to express the idea that it may be appropriate to take actions to prevent potentially harmful climate-change outcomes. This stronger form assumes extreme risk-aversion, since it focuses exclusively on the worst possible outcomes. It is clear, though, that there are costs associated with climate policies that could, under some circumstances, impose large costs on particular peoples and/or nations; but neither form of the precautionary principle has yet been applied to this side of the climate calculus.

Uncertainty also bears on the design of mitigation policies. The problem of climate change might be addressed most effectively through a process of sequential decision making, in which policies are adjusted over time as new scientific information becomes available and uncertainties are reduced. Moss and Schneider (2000) offer guidance on how subjective probabilities can be utilized effectively when empirical data are not available or are inconclusive. New information is valuable, and flexible policies that can make use of this information have an advantage over rigid ones that cannot. In any case, policies that help build or strengthen mitigation capacity are consistent with the insurance approach. To the extent that mitigation capacity is higher, the costs of future action can be expected to be lower.

Technological Uncertainty

Costing climate change policy is an uncertain business. This uncertainty often manifests itself in the choice of technologies to mitigate and adapt to risks from climate change. Firms and nations can attempt to reduce risk by using more of the low-carbon technologies presently on the shelf or they can invent new ones. How quickly people will switch within the set of existing technologies with or without a change in relative energy prices is open to debate; how creative people are at inventing new technologies given relative prices is also a matter of discussion. The key to addressing uncertainty is to capture a range of reasonable behaviors that underpins the choice to adopt existing or develop new low-carbon technology. Two key questions that should be addressed are:

What explains the rate of adoption of existing low-carbon technologies given the relative price of energy?

What explains the rate of invention of new low-carbon technologies given relative prices?

Which answers to these questions are accepted determines whether some weighted average of the estimates or a lower or upper estimate is used to guide policy. For any given target and set of policy provisions, costs decline when consumers and firms have more plentiful low-cost substitutes for high-carbon technologies. Engineering studies suggest 20%-25% of existing carbon emissions could be eliminated (depending on how the electricity is generated) at low cost if people switched to new technologies, such as compact fluorescent light bulbs, improved thermal insulation, heating and cooling systems, and energy-efficient appliances. The critical issue is how this adoption of efficient technologies occurs in practice and which sort of regulation and economic instruments could eventually support this adoption. Energy efficiency matter to consumers, such as a new technology's quality and features, and the time and effort required to learn about it and how it works. This issue has already been flagged in relation to technology adoption and implementation costs, but it also has an uncertainty element to it. The different viewpoints on the origin of technological change appear in the assumed rate at which the energy-consuming capital can turnover without a change in relative energy prices. Modellers account for the penetration of technological change over time through a technical coefficient called the "autonomous energy efficiency improvement" (AEEI). The AEEI reflects the rate of change in energy intensity (the energy-to-GDP ratio) holding energy prices constant (IPCC, 1996a).

The presumed autonomous technological improvement in the energy intensity of an economy can lead to significant differences in the estimated costs of mitigation. As such, many observers view the choice of AEEI as crucial in setting the baseline scenario against which to judge the costs of mitigation. The costs of mitigation are inversely related the AEEI– the greater the AEEI the lower the costs to reach any given climate target. The costs decrease because people adopt low-carbon technology of their own accord, with no change in relative prices. Modellers have traditionally based the AEEI on historical rates of change, but now some are using higher values based on data from bottoms-up models and arguments about "announcement effects". For instance, some analysts have optimistically argued that the existence of the Kyoto Protocol will accelerate the implementation of energy efficient production methods to 2% per year or more. Policymakers and modellers continue to debate the validity of this assumption (see, e.g., Kram, 1998; Weyant, 1998). A range of AEEIs has been adopted in the modeling literature. The AEEI has ranged from 0.4% to 1.5% per year for all of the regions of the world, and has generated large differences in long-term project baselines (Manne and Richels, 1992).

A thread that runs through much of the discussion of costs is that of uncertainty. The whole exercise of estimating mitigation costs is confounded by imprecise information about baselines, and the costs of mitigation and adaptation measures (especially future costs). It is critical that such uncertainties be recognized and conveyed to the policymakers in the most effective manner possible. As discussed above, uncertainty about baselines is best dealt with by taking more than one baseline and reporting cost estimates for multiple baselines. Hence costs should not be given as single values, but as ranges based on the full set of plausible baselines. Technological uncertainty is another key area. This is not easy to overcome by endogen zing technical change, as practical models currently available have difficulties in dealing with endogenous technical change. Thus, the way firms develop new technologies is probably an issue surrounded by a greater uncertainty than uncertainty on the consumer side. There is a moderate degree of consensus in the literature on these issues. As with baselines, a scenario approach is essential and results have to be reported for both "optimistic" and "pessimistic" development paths. Taking a different approach, the way consumers adopt existing lower carbon technologies and firms develop new ones can be viewed as key sources of uncertainty in costing methodologies. These assumptions are crucial, as different valuations are likely to affect the conclusions. However, the ways in which guidance and information about these two crucial issues are provided are radically different. Two different options are available from the consumer side. First, energy oriented macro econometric models can provide a price elasticity to show how changes in the fuel mix are driven by relative prices. However, differences in the results in terms of different energy structures (and different carbon impacts) could easily emerge. Second, engineering studies can provide some indications about available lower energy technologies to show the impact on energy demand and carbon emissions. Hence, from the point of view of uncertainty there is no a priori reason to choose between bottoms-up and top-down models. Finally there are uncertainties in the estimated costs as well as in the estimation of the ancillary benefits and/or co-benefits. Uncertainty about the external costs is well recognized. As with the private costs, again a scenario approach that gives a range from low, through mid, to high values is recommended. In both cases the scenario approach provides a sensitivity analysis for the costing exercise. In the crosscutting paper on uncertainty (Moss and Schneider, 2000), a number of scales are proposed to assess the level of imprecision in the reported impacts, costs, etc. One that has frequently been used for costing exercises is the three-point scale that seeks to evaluate the degree of confidence in a particular result using a scale of: low, medium, and high confidence levels. This has been expanded to a five-point scale, which asks the researcher to select one of the following:

- "Very high confidence" (over 95% certain);
- "High confidence" (67%–95% certain);
- "Medium confidence" (33%–67% certain);
- "Low confidence" (5%–33% certain); and
- "Very low confidence" (below 5% certain).

This has not been applied to cost estimates, but it would useful to establish whether it could be applied and, if so, whether it would provide policymakers with better guidance as to the reliability of the results.

Uncertainty Is Pervasive: There are many uncertainties regarding the magnitude of future climate change, its consequences and the costs, benefits and implementation barriers of possible solutions. Future emissions to the atmosphere are inherently uncertain and can only be explored on the basis of scenarios. The change in concentration of GHGs that would result from a given emission rate is much less uncertain. But the timing, extent, and distribution of climate change and sea level rise for a given concentration of GHGs is not well known due to limitations in modeling climate change at the regional level. The cost implications of emissions mitigation are better known than the more distant (in time) potential benefits from mitigation. In part this is because of temporal proximity, but it is also because most of the costs associated with emissions mitigation pass through markets, whereas many of the benefits do not. Some uncertainties will remain unresolved regardless of the decisions made. This follows directly from the fact that there is only one observed history. All the other potential histories are counterfactual, and therefore constructs from analytical tools that are limited in their veracity. In decision making terms the problem of climate change mitigation requires decision making under uncertainty. Given the long lead times of mitigation action, fully resolving would make an adequate response infeasible.

2.3. Mitigation opportunity and potential by sector

2.3.1. Mitigation in Agricultural sector

CH_4 emissions from agriculture produce about eight per cent of the radiative forcing of all GHGs (Watson et al., 1996). CH_4 from manure can be captured and used for fuel; emissions from ruminants can be reduced with better diets, feed additives, and breeding; and emissions from rice paddies can be mitigated by nutrient management, water management, altered tillage practices, cultivar selection, and other practices (Mosier et al., 1998).

Many of the mitigation options to address these opportunities may provide multiple benefits to the farmer and society at large. Improving soil management for crop production, for instance, can also improve water relations, nutrient retention, and nutrient cycling capacity (Paustian et al., 1998). Retiring surplus agricultural lands can result in improved water quality, reduced soil erosion, and increased wildlife habitat. As Izac (1997) points out, however, farmers, who will be the ultimate decision makers about which mitigation option to adopt, have shorter planning horizons than national or international beneficiaries, and many mitigation options ask them to bear costs up front while the benefits are longer term and to the society at large.

Furthermore, in order to realize these opportunities a very large proportion of farmers who pursue diverse agricultural practices will have to be convinced to adopt mitigation options. Economic, cultural, and institutional barriers exist which restrict the rate of adoption of such practices. Farmers who are accustomed to traditional practices may be reluctant to adopt new production systems. Crop price supports, scarcity of investment capital, and lack of economic incentives for addressing environmental externalities are some of the economic barriers. Limited applicability of mitigation options to different types of agriculture, negative effects on yield and soil fertility for rice production, and the increased skilled labour requirements are some of the other constraints. Among these barriers the especially critical ones are highlighted here.

Good Agricultural Practice

Many practices have been advocated to mitigate emissions through the mechanisms cited above. Often, a practice will affect more than one gas, by more than one mechanism, sometimes in opposite ways, so the net benefit depends on the combined effects on all gases (Robertson and Grace, 2004; Schils et al., 2005; Koga et al., 2006). In addition, the temporal pattern of influence may vary among practices or among gases for a given practice; some emissions are reduced indefinitely, other reductions are temporary (Six et al., 2004; Marland et al., 2003a). Where a practice affects radiated forcing through other mechanisms such as aerosols or albedo, those impacts also need to be considered (Marland et al., 2003b; Andreae et al., 2005).

Because often intensively managed, croplands offer many opportunities to impose practices that reduce net GHG emissions. Mitigation practices in cropland management include the following partly-overlapping categories:

Agronomy: Improved agronomic practices that increase yields and generate higher inputs of carbon residue can lead to increased soil carbon storage (Follett, 2001). Examples of such practices include: using improved crop varieties; extending crop rotations, notably those with perennial crops that allocate more carbon below ground; and avoiding or reducing use of bare (unplanted) fallow (West and Post, 2002; Smith, 2004a, b; Lal, 2003, 2004a; Freibauer et al., 2004). Adding more nutrients, when deficient, can also promote soil carbon gains (Alvarez, 2005), but the benefits from N fertilizer can be offset by higher N_2O emissions from soils and CO_2 from fertilizer manufacture (Schlesinger, 1999; Pérez-Ramírez et al., 2003; Robertson, 2004; Gregorich et al., 2005). Emissions per hectare can also be reduced by adopting cropping systems with reduced reliance on fertilizers, pesticides and other inputs (and therefore, the GHG cost of their production: Paustian et al., 2004). An important example is the use of rotations with legume crops (West and Post, 2002; Izaurralde et al., 2001), which reduce reliance on external N inputs although legume-derived N can also be a source of N_2O (Rochette and Janzen, 2005). Another group of agronomic practices are those that provide temporary vegetative cover between successive agricultural crops, or between rows of tree or vine crops. These 'catch' or 'cover' crops add carbon to soils (Barthès et al., 2004; Freibauer et al., 2004) and may also extract plant available N unused by the preceding crop, thereby reducing N_2O emissions.

2.3.2. Mitigation in forest sector

The forestry sector faces land use regulation and other macroeconomic policies that usually favour conversion to other land uses such as agriculture, cattle ranching, and urban industry. Insecure land tenure regimes, and tenure rights and subsidies favouring agriculture or livestock are among the most important barriers for ensuring sustainable management of forests as well as sustainability of carbon (C) abatement. The Special Report on Land Use, Land-use Change and Forestry (IPCC, 2000a) notes significant opportunities for forestry and other land-use change activities to sequester carbon. Afforestation and reforestation activities could capture between 197 to 584MtC/yr in all countries under the IPCC "definitional" scenario between 2008 to 2012. The estimated deforestation, however, would negate this sequestration potential. Halting deforestation offers additional opportunity to reduce emissions. Forest management and agroforestry options offer a potential to capture another 700MtC/yr by 2010. Capturing these opportunities, however, entails significant hurdles of the types noted below.

2.3.3. Mitigation in Forestry

Under the GEF-UNDP sponsored Asian Least-Cost Greenhouse Gas Abatement Strategy (ALGAS), the US Country Studies Program (Sathaye et al., 1997a), and other forestry sector capacity building and analytical activities have identified mitigation options and technologies. Furthermore, the policies to promote technology transfer have been identified (e.g., regulations, financial incentives) and sometimes implemented (e.g., Mexico, Bolivia). Under the UNFCCC, each party is required to communicate a national inventory of GHG emissions by sources and sinks. A large portion of the parties has completed this task and is trying to understand forestry sector emissions and removals by sinks, which has improved dramatically. Many parties are taking steps to manage forest systems as C reservoirs (Kokorin, 1997; Sathaye et al., 1997a).

As a result of the UNFCCC and Kyoto Protocol, many developing and transitional countries are developing National Climate Change Action Plans (NCCAPs) which incorporate forestry-sector mitigation and adaptation options (Benioff et al., 1997). ''No regrets'' adaptation and mitigation options have been identified that are consistent with national sustainable development goals. Bulgaria, China, Hungary, Russia, Ukraine, Mexico, Nigeria, and Venezuela all have developed very specific forestry sector climate action plans.

Forestry mitigation projects are likely to be largely funded by Annex I countries and implemented in non-Annex I countries and EITs. Technology, including management systems, is an integral part of all projects funded by bilateral or multilateral or commercial agencies. Thus, promotion of mitigation projects also automatically promotes the flow of technology from donor agencies or countries to host countries or agencies. In fact, technology transfer is already happening. Forestry sector options are of relatively low cost compared to those in the energy sector (Sathaye and Ravindranath, 1998). But there are some problems and uncertainties regarding the incremental C abated: its sustainability, measurement, verification, and certification. All forestry sector GHG mitigation projects must ensure that they meet accepted standards for sustainable forest management (Sathaye et al., 1997b). Independent verification of C abatement would help to increase the credibility and funding of forestry-sector mitigation projects.

Reducing Emission from Deforestation and Forest Degradation (REDD)

REDD is a mechanism that has been under negotiation by the United Nations Framework Convention on Climate Change (UNFCCC) since 2005. REDD has two objectives, first is to reduce emissions of greenhouse gases and second is to remove greenhouse gases through enhanced forest management in developing countries. In the last two decades, various studies estimate that land use change, including deforestation and forest degradation, accounts for 17-29% of global greenhouse gas emissions (Philip Fearnside, 2000; Myers, Erin C., 2007; G.R. van der Werf et al., 2009). For this reason the inclusion of reducing emissions from land use change is considered essential to achieve the objectives of the UNFCCC (World Bank, 2004).

REDD was first discussed in 2005 by the UNFCCC at its 11th session (Montreal on December 2005) of the Conference of the Parties to the Convention (COP) at the request of Costa Rica and Papua New Guinea, on behalf of the Coalition for Rainforest Nations, when they submitted the document "Reducing Emissions from Deforestation in Developing Countries: Approaches to Stimulate Action", it is requested to create an agenda item to discuss consideration of reducing emissions from deforestation and forest degradation in natural forests as a mitigation measure. COP 11 entered the request to consider the document as agenda item. The Bali Action Plan decided at the COP at its thirteenth session7 states that a comprehensive approach to mitigate climate change should include: “Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.”

According to the FAO (2005), deforestation, mainly conversion of forests to agricultural land, continues at an alarming rate of approximately 13 million hectares per year (for the period 1990–2005). Deforestation results in immediate release of the carbon originally stored in the trees as CO_2 emissions (with small amounts of CO_2 and CH_4), particularly if the trees are burned and the slower release of emissions from the decay of organic matter. The IPCC WGIII (2007) estimated emissions from deforestation in the 1990s to be at 5.8 $GtCO_2$/yr. The IPCC also notes that reducing and/or preventing deforestation is the mitigation option with the largest and most immediate carbon stock impact in the short term per hectare and per year globally as the release of carbon as emissions into the atmosphere is prevented.

The COP has adopted a number of decisions on REDD-plus, most recently at its 19th session the “Warsaw Framework for REDD-plus” (WFR). REDD is a solution to the problem. More recently, the “+” in REDD+ has drawn increasing attention towards the activities after the semicolon, related to the conservation and enhancement of carbon stocks. A future REDD mechanism has the potential to deliver much more. REDD could simultaneously address climate change and rural poverty, while conserving biodiversity and sustaining vital ecosystem services. Although these benefits are real and important considerations, the crucial question is to what extent the inclusion of development and conservation objectives will either promote the overall success of a future REDD framework or complicate and therefore possibly hamper the ongoing process of REDD negotiations. The COP established a contact group and thereafter began a two year process to explore options for REDD. This decision resulted in a wide range of Parties and observers over this period submitting proposals and recommendations to the Subsidiary Body on Scientific and Technical Advice (SBSTA) to reduce greenhouse gas (GHG) emissions from deforestation and degradation. We are now at the stage where we have a number of proposals on the table. Under the Bali Action Plan, if REDD is to be included in a post-2012 framework, a decision about what a REDD mechanism will look like and what it will include needs to be agreed by COP15 in Copenhagen in December, 2009. Reaching a consensus on this issue is of paramount importance for a global deal on climate change (STERN &Nicholas, 2008).

2.3.4. Mitigation in Energy sector

There are varying over sectors and regions in mitigation choices and benefits of mitigation options for sustainable development. Generally, mitigation options that improve productivity of resource use, whether it is energy, for instance, improved management practices use of bioenergy and efficient cooking stoves enhance productivity, and other categories of mitigation options have a more uncertain impact and depend on the wider socio-economic context within which the option is being implemented.

For instant, the based-line or reference scenario by ADB in collaboration with the former Ministry of Industry, Mine and Energy (MIME) indicated that the Household sub-sector has the highest energy demand at 86.4% in 1994 (Table 2), but in Table 2, it is only second in the Global Warming Potential (GWP) emissions at 37%, transport being the highest at 42.6%. This is due to the fact that Households use mainly biomass, which is not accounted for in the GWP calculations since its CO_2 emissions are considered to be absorbed by the forest. In this scenario, the total GHG emissions accumulated from 1994 to 2030 is 251,593 Gigagram (Gg) of CO_2 equivalent (Table 3).

Table 2 Energy Demand in Million Gigajoules (Reference Scenario)

Sector	1994	%	2000	%	2010	%	2020	%	2030	%
Household	79.475	86.4	90.106	80.6	113.979	71.7	142.118	61.4	166.287	48.0
Industry	0.522	0.6	0.868	0.8	2.254	1.4	4.866	2.1	14.711	4.2
Service	0.918	1.0	1.418	1.3	3.183	2.0	7.816	3.4	20.056	5.8
Transport	11.072	12.0	19.337	17.3	39.453	24.8	76.694	33.1	145.288	41.9

Sum	91.987	100	111.728	100	158.869	100	231.494	100	346.342	100

Table 3 Table … GWP in Gg of CO2 Equivalent (Reference Scenario)

Sector	1994		2000		2010		2020		2030		1994-2030	
	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
Household	685	37	775	29.6	980	20.5	1,219	13.9	1,421	8.7	38,438	15.3
Industry	6	0.3	11	0.4	28	0.6	61	0.7	187	1.1	2,024	0.8
Service	4	0.2	6	0.2	11	0.2	25	0.3	54	0.3	729	0.3
Transport	789	42.6	1,374	52.4	2,799	58.6	5,444	62.1	10,329	63.0	151,665	60.3
Transformation	369	19.9	456	17.4	962	20.1	2,012	23.0	4,416	26.9	58.737	23.3
Total	1853	100	2,622	100	4,780	100	8,761	100	16,407	100	251,593	100

Comparing the 1994 GHG emissions of Cambodia in the energy sector (1,853 Gg of CO2 equivalent) to the 1990 emissions of Vietnam (27,497 Gg of CO2 equivalent), Myanmar (6,086 Gg of CO2 equivalent), Philippines (43,473 Gg of CO2 equivalent) and Thailand (79,659 Gg of CO2 equivalent), Cambodia has the lowest emissions in the region. The total country GHG emissions per capita in Cambodia and Indonesia both have negative emissions of 0.52 and 0.4 tonnes of CO2-equivalent per person, respectively. The negative figures mean that both are net carbon sink countries, where their respective forestry sectors were able to absorb all the CO2 emissions and have excess capacity to absorb more.

Switching to low carbon energy supply sources is the other mitigation category in the energy sector with significant GHG benefits. This can be achieved through either increased reliance on imported or indigenous alternative fuels. Using a higher proportion of low carbon imported fuels will almost always reduce local air pollution. Its direct impact will be to increase payment for fuel imports that may result in worsened balance of payments, unless these are utilized to increase a nation's exports (Sathaye et al., 1996).

Economies and societies of low carbon fuel exporting countries would benefit from the higher trade. Increased reliance on most indigenous low carbon energy sources would also reduce local air pollution, but the local environmental benefits in certain solid bioenergy applications appear to be uncertain. While indigenous low carbon fuels can reduce fuel imports, these have to be balanced against higher capital requirements for investment in fuel extraction, processing and delivery (Sathaye et al., 1996). The development of large hydro sources can displace local populations and put their livelihood in jeopardy, and in reservoirs with large surface area, the resulting methane emissions may reduce their net GHG benefit substantially. For example, although hydroelectric plants have the potential to reduce GHG emissions significantly, a large amount of literature points to important environmental costs (McCully, 2001; Dudhani et al., 2005), highlights the social disruptions and dislocations (Sarkar and Karagoz 1995; Kaygusuz, 2002), and questions the long longterm economic benefits of major hydropower development.

Increased use of indigenous low-carbon fuels can reduce export of fuels from other countries to the extent the latter are substituted away. These may adversely affect the trade balance of exporting countries (Sathaye et al., 1996). At the same time, low carbon fuels can have other environmental benefits. For example, a move away from coal to cleaner fuels will reduce ecosystem pressures that often accompany mining operations (Azapagic, 2004). Similarly, a move away from charcoal and fuel wood as a source of energy will have the attendant environmental benefits of reducing the pressures of deforestation (Masera et al., 2000; Najam and Cleveland, 2003). These points are towards the need to optimize technology choice decisions not only along the dimension of carbon emissions but also other environmental costs.

2.3.5. Mitigation in Hydropower

The Government recognizes that the high cost, unreliability, and limited geographic availability of electricity still constitutes a major hindrance to private sector and rural development. The high cost reflects the almost total dependence on imported oil based fuel as the primary energy source, and the lack of a high voltage transmission system. The state-owned utility, Electricité du Cambodge (EDC), will therefore undertake the rehabilitation of the 10 MW hydropower plant in Kampong Speu province. The other hydropower plants identified in the study "Power Transmission Plan and Rural Electrification Strategy", and adopted by the MIME, were all evaluated in this study.

The Royal Government of Cambodia (RGC), together with major donors and NGOs have developed energy policies and energy supply projects such as high voltage power transmission lines, hydropower development, improvement of mass transit, improved cook stoves, etc.. These policies and projects were not identified as GHG Mitigation projects, but if implemented will actually reduce the GHG emissions of the country. Furthermore, these plans were not considered in the MIME study, which was used as the basis of the baseline scenario in this study because the above plans were only finalized after the completion of the MIME study. Given this, a scenario called "Government Plans" was created in this study to describe these projects in detail. LEAP 2000 can calculate the GWP emissions and reductions and the Cost of Saved Energy (CSE) of these projects, depending on the availability of data. The Government Plans scenario has reduced the GHG emissions by 14% from the reference scenario (Table 4).

Table 4 GWP Reduction

SCENARIO	GWP Reduction (2003-2030) Gg of CO_2 Equivalent	% Reduction (of Total GWP)	Incremental Cost* $'000/Gg CO_2
A. GOVERNMENT PLANS			
1. Combined Cycle Gas Turbine	19,980	41.9	9.32
2. Hydropower	12,390	25.9	10.32
3. Phnom Penh City Shuttles	2,300	4.8	1.29
Total Reduction (14%)	34,670	100	
B. MITIGATION OPTION			
4. Improved Cook Stove (ICS)	13,060	52.3	-1.02
5. Compact Fluorescent Lamp	7,320	29.3	-2.48
6. Mass Transit (Rural)	4,600	18.4	1.29
Total Reduction (10)	24,980	100	

C. **HIGH SCENARIO (A+B) (24% Reduction)**	59,650		

[*] Incremental Cost taken from the ALGAS Report

The state-owned utility, Electricité du Cambodge (EDC), will therefore undertake the following initiatives during SEDPII:

- Rehabilitation of the 10 MW hydropower plant in Kampong Speu province and of the 115KV transmission line to supply Kampong Speu town and Phnom Penh;
- Implementation of the agreement to establish the HV 220KV interconnection with Vietnam to supply Phnom Penh;
- Investigation of lower voltage cross-border transmission lines to supply towns close to the Thai and Vietnamese borders; and
- Investigation of 115KV transmission line from Thailand to supply SereySisophon in BanteayMeanchey province, with possible later extension to Siem Reap and Battambang.

To meet the growth in demand, which is forecast to grow from 97 MW and 522 GWh in 1998 to 746 MW and 2634 GWh in 2016, the Royal Government has decided to develop a National Transmission System. This System will allow access to energy generated by efficient large-scale power stations to provincial centers and also allows Cambodia to access available hydroelectric sites inside Cambodia or in neighboring countries. It will significantly reduce reliance on imported oil for the energy generation and also the risks involved in oil transportation.

The total capital cost of transmission developments within the period (1999-2016) is about $365 million excluding contingencies. It is proposed that the transmission system be developed in three stages depending on the availability of funds. A national transmission system can allow trading of electricity from systems that may have excess capacity, at a lower cost and may produce less GHG, for example, importing cheaper electricity from Vietnam. This transmission line can also be used to export electricity to Vietnam. In the case of large hydroelectric power plants, which are considered uneconomical if the demand is not enough to effect economies of scale, once connected to the grid this project will be economically feasible. A new and efficient transmission line will result in reduced transmission losses and will have reduced generation requirements, with subsequent reductions in GHG emissions. In order to ensure that these large hydroelectric power plants will not result in flooding of forests and communities, the government should strictly implement the submission of EIA and other environmental rules and regulations.

The 220 kilowatt high voltage transmission line will minimize transmission losses. 80% of the losses occurring during transmission and distribution are due to resistance, which is inversely related to voltage-therefore, the higher the voltage, the lower the transmission and distribution (T&D) losses. Electrical resistance losses in high voltage systems are low, making it well suited for bulk transfer of electricity over large distances. Cambodia has also trade electricity with neighboring countries to improve system reliability and to reduce electricity costs, trading arrangements with neighboring countries will be negotiated. There are plans to purchase low level energy (22 kV) from Vietnam, Thailand and Laos. This power will be provided to provincial towns and districts close to the borders of the three countries mentioned.

There are also plans for low capacity transmission links (115 kV) from Aranyaprathet in Thailand to BanteayMeanchey, Battambang and Siem Reap and connection from Vietnam to Takeo. Large capacity transmission links (230 kV or 500 kV) dedicated to energy imports/exports with Vietnam is tentatively planned to take place between 2002 and 2008. Cambodia is negotiating with Thai authorities to create links in Western Cambodia, specifically Battambang, Siem Reap and Banteay Meanchey provinces, and both authorities have agreed upon the areas for the connections and are finalizing plans."

Power trade has already commenced with cross border connection to the Thai grid established to supply Koh Kong and Poi Pet and further local area cross border connections are in the planning stage for connections to the Thai and Vietnamese grids.

The first national power transmission line between Phnom Penh and the Vietnamese border will bring cheaper, more reliable power supplies to Cambodia. The power from Vietnam will help Cambodia solve its power shortage. Creating the $46 million power link with Vietnam is the beginning of a 10-year electricity and power project in Cambodia".

Cambodia plans to spend another $82 million to build a national power grid that will supply Cambodia and neighboring countries with electricity, reducing Cambodia's dependency on foreign electricity. Both the link from Vietnam and the power grid project will be financed with loans from the World Bank. The Cambodian-Vietnamese power link will include two connections. The first link is a medium voltage 15 or 22 kilowatt line that will benefit villages on both sides of the border. The second, larger union is a 220-kilowatt high-voltage transmission line that will run from the Vietnam border to Takeo town and then to Phnom Penh.

Most Cambodians in rural areas pay approximately $0.17 per kilowatt-hour, which is $0.10 higher than what most Vietnamese pay. The new electricity transmission line will reduce the price to around $0.11 - $0.12 per kilowatt-hour. The $0.11 or $0.12 will be a flat fee for 12 years and will offset the cost of the project. Businesses in Phnom Penh will also benefit from this power link. The cost of power for business and industries in Cambodia will drop from the current &0.21 per kilowatt-hour to between $0.11 and $0.14 per kilowatt-hour. Table5 below is the hydropower project in Cambodia.

Table 5 List of Hydropower Project in Cambodia

Name of CDM Project Activity	Type of Project	Supplemental Information	Approval Date (d/m/y)	Annual Emission Reduction (t-CO_2/yr)	Project Participants (Host Country)	Project Participants (Others)	Status
Lower Stung Russei Chrum Hydro-Electric Project	Hydor	New reservoir		70,199	China Huadian Lower Stung Russei Chrum Hydro-Electric Project (Cambodia) Co., Ltd.	Vitol S.A	Under Validation
Cambodia Stung Atay Hydropower Project	Hydro	New reservoir		266,472	C.H.D (Cambodia) Hydropower	Gazprom Marketing &	Under Validation

						Trading Singapore Pte. Ltd.	
Kamchay Hydroelectric BOT Project	Hydro	New reservoir	20/11/08	281,348	Sinohydro Kamchay Hydroelectric Project Co., Ltd	CF Carbon Fund II Ltd.	Under validation
Stung Tatay Hydroelectric Project	Hydro	New Reservoir		563,074	Cambodian Tatay Hydropoer Ltd	Gazprom Marketing & Trading Singapore Pte. Ltd.	Under validation

Source: CCD, MoE; IGES CDM Project Database < http://www.iges.or.jp/en/cdm/report.html >

2.4. Land use, land use change and forestry

2.4.1. Greenhouse gas and emission from land use change and forestry

Currently, Cambodia's GHG emissions levels are low. According to the World Resources Report 1996-97 (WRR), land-use change in 1991 accounted for 35 million tonnes of CO2 emissions, although these and any other estimates have to be acknowledged as extremely uncertain. The WRR estimated that energy and industrial-related emissions accounted for only 462,000 metric tonnes in the same year, and that methane emission in 1989 were 1.1 million metric tonnes per year from a combination of rice and livestock production. Recovery of the country from its recent history, as well as economic development, is likely to dramatically increase land-use and energy related emissions of GHGs over time.

The inventory of GHG emissions by sources and removal by sinks indicates that in 1994, Cambodia removed 64,580 Gg and emitted 59,708 Gg of CO2-equivalent. Therefore, in 1994, Cambodia was a net carbon sink country with a net total carbon removal of 5,142 Gg of CO2 equivalents (MoE, 2001). The main source of carbon dioxide emissions was land use change and forest sector (LUCF; 97%), followed by energy (3%), while the contribution from the industry sector to total CO2 emissions was insignificant. However, the capacity of the LUCF sector to uptake CO2 was 43% higher than emissions, thus in total this sector could offset all other GHGs emissions from all other sectors. The CO2 emissions from LUCF, energy and industry were approximately 45,214; 1,272 and 50 Gg respectively, while CO2 removal by LUCF was 64,850 Gg.

It is important to note that if some of the assumptions used in the Land Use, Land Use Change and Forestry (LULUCF) sector in particular were changed, the country's GHG emission status may change considerably. Many studies indicated that biomass removals through illegal logging are quite significant. The World Bank report on illegal logging indicated that in 1997/98 at least 4.25 million M3 of round wood were removed from forests through illegal logging (World Bank, 1999). Thus, the effect of including illegal logging in the calculation of GHG emissions from LUCF may change the status of Cambodia significantly. For example, if illegal logging was included and the mean annual increment (MAI) or growth rate of evergreen, mixed & coniferous and deciduous forest was changed from the current values, emissions from LULUCF would change considerably and may change the country's status from a net sink to a net emitter. The detailed analysis, however, could not been done under this inventory due to the lack of reliable data on illegal logging and local MAI. At present the MAI used for the analysis was not local data but IPCC default values for evergreen and Thailand data for mixed & coniferous and deciduous forests. This indicates how important this sector is in regards to GHG emissions. Therefore identification of

GHG mitigation options in this sector is very important not only for reducing the emissions but also for the prosperity of the country.

2.4.2. Land use, land use change and forestry in Cambodia

Cambodia as an agricultural economy, considers land use change and forestry as important issues related to climate change. Forests are among Cambodia's most important natural resources. In ecological and environmental terms, Cambodia's forests are invaluable. Forests protect the soil from erosion, stabilize the watersheds and regulate water flow and local and regional climate systems. Forests have long offered rural Cambodians essential livelihood benefits, supplementing agricultural or fishing activities by providing construction materials, medicines, food, and market goods. Wood fuel accounts for over 80% of the total energy requirement of the country and much of the wood fuel is a by-product of forest reduction.

Cambodia comprises an undulating plateau in its eastern part, a continuous flat plain (the Lake Tonle Sap lowland) interrupted only by isolated hills (Phnoms) and the Mekong River in the central part of the country, highlands to the north and northeast and the Cardamom Mountains in the south-west. The agricultural area was estimated at 5.5 million hectares (ha) in 2009, with estimated cultivated areas totaling 4.1 million ha. 96% of this area was used for annual crops and 3.8% for permanent crop (AGEG, et al., 2012). The Ministry of Agriculture, Forestry and Fisheries (MAFF) published a chart in 2001 to represent the overall distribution of land use in Cambodia, including 59% as forest land (Figure 1). Since then the Forestry Administration (FA) has reported a forest cover figure of 57% (2010), despite the obvious rapid expansion of urban areas for residential and industrial land use.

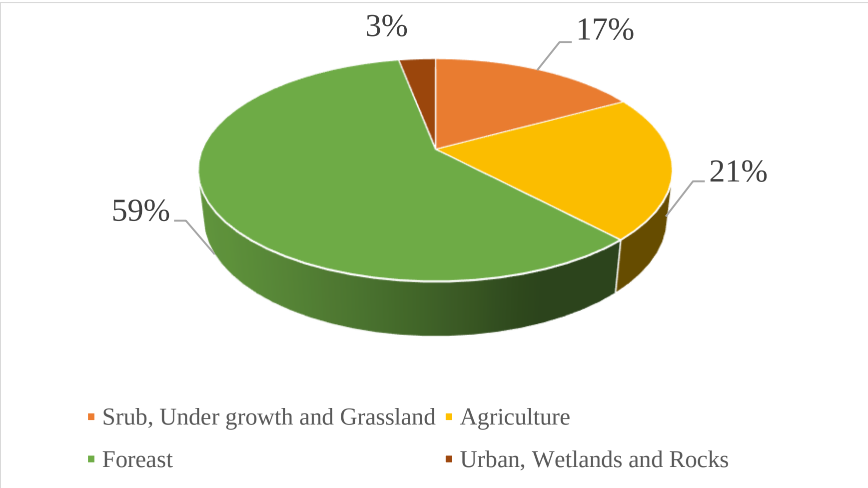

Figure 1 Land Use in Cambodia

Source: AGEG, et al., 2012

2.4.2.1. Status and Trends in Forest Sector

The 20-year National Forest Program (NFP) was formally approved by RGC's Council of Ministers in May 2010 and is being promoted by government and development partners alike as a key guiding document for the sector. It identifies nine strategic priorities, including contribution to the economy, climate change, forest governance, conservation of forest resources, improved forest management and sustainable financing of the program itself. The MAFF's FA agrees to 57% forest cover in 2012, which is less than the 60% policy goal. In recent years FA has redefined forest cover to include plantations of rubber, coffee and other tree crops (AGEG, et al., 2012).

The total area of forest in Cambodia is estimated at 10,864,186 ha, equivalent to approximately 60% of the total land area. The country's forests have suffered from both deforestation and degradation. Around 2.1 million hectare of forestland were converted to agricultural land other uses between 1960 and 19992-93 (UNDP, 2011).

Table 6 Table 2. Area of Cambodia's Forest/Biomass Stocks in 2000

Forest/Plantation Type	Area of Forest/Biomass Stocks (ha)
Acacia spp.	3,700
Eucalyptus spp.	5,549
Hevea brasiliensis	36,000
Evergreen	3,718,000
Semi-Evergreen	1,339,000
Deciduous	4,176,000
Inundated	234,627
Mangrove	69,000
Other (Arbor Day)	119

Source: FA 2009; UNDP 2011

The FA has conducted national forest cover change assessment for 2006 using Landsat ETM+ satellite imagery data; this resulted in forest cover statistics for 2006 and a forest cover map. Forest cover between 2002 and 2006 declined from 61% to 59%. This means that forest area lost 2% of the total land area. The 2% decline in forest cover represents an estimated loss of 373,510 hectares of forest (FA, 2010).

Table 7: The forest cover change 2002-2006

No	Forest Types	Forest Cover Area				Change 2002-2006	
		2002		2006			
		Ha	%	Ha	%	Ha	%
1	Evergreen forest	3,720,493	20.49	3,668,902	20.20	-51,591	-0.28
2	Semi evergreen forest	1,455,183	8.01	1,362,638	7.50	-92,545	-0.51
3	Deciduous forest	4,833,887	26.62	4,692,098	25.84	-141,789	-0.78
4	Others forest	1,094,728	6.03	1,007,143	5.55	-87,585	-0.48
	Total forest land	**11,104,291**	**61.15**	**10,730,781**	**59.09**	**-373,510**	**-2.06**
5	Non forest	7,056,383	38.85	7,429,893	40.91	373,510	2.06
Total areas		**18,160,674**	**100**	**18,160,674**	**100**		

2.4.2.2. The Root of Causes deforestation

Deforestation, including reductions in tree density and cover, has been widespread in Cambodia. Deforestation is often associated with rural poverty and population growth, which force rural people to encroach onto forest areas to find new cultivatable land and to harvest forest products to increase their income. In 1998, Associates in Rural Development (ARD) stated that with the then current population growth rate of 3%, the population of Cambodia would double in size within the next twenty-five years, resulting in greater pressure on forest land.

Wood is the main source of cooking fuel in Cambodia. In 1996, it was estimated that half of all fuel wood was extracted from forests (Table 8). The production of fuel wood and charcoal in forest supply areas close to roads and rivers may be greater than log production. Over the last thirty years the inability of the state to manage the forest resources has been largely due to the war which ended in 1998. In the last five years, logging increased due to the need for increased income. Log production reached the highest levels in Cambodia in 1997 with 4.3 million cubic meters being cut from over 7 million hectares of forests. Illegal timber felling accounted for at least 92% of total production (Bottomley, 2000).

FAO (1994) and Global Witness (1996) reports, in addition to Government statistics, stated that there were 11 forest concessions covering 2.2 million hectares of forest before 1994. By 1999, there were 20 companies holding valid agreements for 24 concession blocks which covered an area of approximately 4,627,653 ha. Other studies indicate that approximately 6,464,021 hectares have been allocated for concessions (World Bank/FAO/UNDP, 1996). However, it was estimated that only 5.6 million hectares have substantial commercial value. The above facts suggest that logging activities, rural poverty and clearance of forests for agricultural purposes are major causes of deforestation in Cambodia.

Table 8 Fuel wood Extractionfrom1961toPresent

Year	**Total Fuel wood (million^3)**	**Extraction from Forest (50%), (million^3)**
1961-1970	18	9
1971-1980	10	5
1981-1990	24	12
1990-present	6	3

Source: World Bank/FAO/UNDP (1996)

From 1999 to 2000, the Royal Government of Cambodia reviewed the contractual compliance of the concessionaires. As a result of the review 11 forest concession agreements covering 16 concession areas (approximately 2,437,970 ha) were terminated. These forest areas have been declared as conservation forests. In addition, the Cambodian Government has also announced a crackdown on illegal logging and has closed down many sawmills. It is expected that these actions will lead to reduced illegal logging activities.

2.4.2.3. Protected Areas

Cambodia was the first country in South-East Asia to establish protected areas. The forests surrounding the temples of Angkor were declared a national park in 1925. By 1969, six wildlife sanctuaries had been set aside covering 2.2 million hectares or 12 percent of the country for the protection of wildlife, in particular large mammals. The long period of civil war led to the effective collapse of the system in any practical sense but over the past decade efforts at biodiversity conservation through protected areas recommenced and intensified. The current national protected area system comprises:

- 23 protected areas covering 3.3 million hectares - more than 18 percent of the country - created through a Royal Decree in 1993 and managed by MOE; and
- A growing number of fish sanctuaries and protected forest areas set up through MAFF.

This brings the national protected area system to over 21 percent of the country. The system also includes provincial protected areas, which are set to significantly increase in number once the current legislative framework and guidelines for protected areas are clearly defined at national level. Ratanakiri province has established thirteen provincial protected areas and five other provinces have expressed interest in following this lead.

Cambodia has one of the highest percentages of national territory within protected areas in the world and has a goal of taking that area to 25 percent by the year 2005.24 It is an exceptional commitment to protected areas as a major component of Cambodia’s national development strategy, and one gradually being recognised internationally (ICEM, 2003).

The Angkor Protected Landscape adjoining the temple complex is listed under the World Heritage Convention and the Tonle Sap Multiple Use Area is identified as a Biosphere Reserve under UNESCO’s Man and Biosphere Program. Cambodia also has three sites designated under the Ramsar International Wetlands Convention. Currently, MOE is seeking to have the Cardamom Mountains Protected Forest and the two adjoining wildlife sanctuaries recognised as a World Heritage Site.

The Royal Government of Cambodia fully recognizes the need for protecting forests for both economic values and environmental benefits. With the support of various donors, it has taken some decisive measures to protect the remaining forest. Cambodia also has a high percentage of the country designated as protected areas. As of 1993, all edaphic forests and some2.8 million hectares of dry land forest were put under the National Protected Area System, which presently has 23 protected areas. The total protected area is 3,568,100 hectares, 19.7% of the country’s total land area. These areas are classified as National Parks, Wildlife Sanctuaries, Protected Landscapes and Multiple-Use Areas. Unfortunately, the effectiveness of management and protection of these areas is very limited. The effectiveness and long-term effect of the current forest and protected areas management practices remain questionable.

2.4.2.4. Community Forestry

Community forestry is an important forest management alternative to industrial forest concession, in which the forest management authority is conveyed to local communities. Approximately 22 small scale community forests (WWF, 2000. Community Forestry Study

Preparatory Report) have already been established in order to ensure the long term security and stability of the livelihood of rural communities that depend on forest products and to increase forest cover. Community forestry has been recognized as an effective strategy for sustainable forest management. To date, most of the community forest projects have focused on developing pilot projects to promote community based management to local communities and to train staff. Both MoE and MAFF have units dedicated to the development of community forestry.

2.4.2.5. Reforestation

From 1985 to 2000 the total area of forest plantation established was 8701 ha (see Table 1.1) which included trees planted on National Arbor Day. The rate of reforestation varies from year to year, beginning with 289 ha in 1985 and increasing to 897 ha in 2000 (Figure 1.2). Acacia and Eucalyptus are the most common tree species planted. The DFW also distributed 2 million seedlings of mixed tree species to local people and various institutions, and cooperated with NGOs conducting extension to local people to protect forests and actively plant trees, especially through school children. The DFW has been promoting the establishment of nurseries throughout Cambodia, selection of appropriate tree species for planting, and expansion of reforestation schemes, forest extension, and community forestry programs. According to a temporary assessment, there are 6 million hectares of degraded forest land that need to be rehabilitated from 2001 to 2005 (Department of Forestry and Wildlife, the Second Five-Year Plan for Forestry Sector, 2001-2002). The specific sites and detailed information is now being studied. As specified in the "Second Five-Year Plan for Forestry Sector, 2001-2005", tree planting programs will be implemented in many forms in provinces and towns with the objective of:

- Planting 50,000 ha/year of forest plantations;
- Planting 120ha/year on National Arbor Day; and
- Planting approximately 16,000ha/yr through people participation and community forestry. The common tree species planted in Cambodia are Acacia, Deperocarpus, Tectonic grand is,

Aphidian coohinchinnensis, etc. In this study, planted trees are classified as reforestation with and without rotation. Acacia falls under category of reforestation with short rotation, and reforestation without rotation with fast growing species. From the 2000 Financial Proposal submitted to the government by the Department of Forestry and Wildlife, it was indicated that Acacia accounted for 73% of all trees planted in reforestation programs. Tectonagrandis, mixed tree and Pahudiacoohinchinnensis accounted for 8, 8 and 3%, respectively.

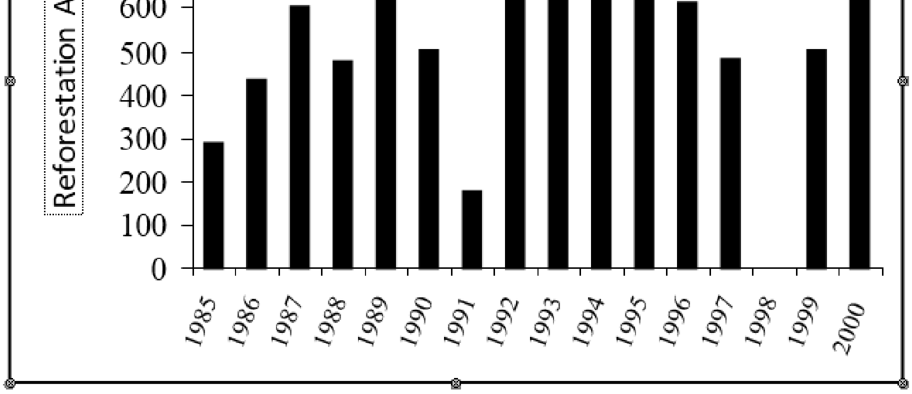

Figure 2 Figure Reforestation Rate in the Period of 1985-2000 (DFW, Statistics of Reforestation)

2.4.3. Assessment of GHG Mitigation options

Substituting the use of fossil fuel-based energy generation with biomass-based energy or the use of biomass products in place of energy-intensive materials (i.e. metals, plastic, glass, etc.) which require large amounts of energy for extraction and processing.

In this study, mitigation options evaluated were forest protection (FP) which falls under category one, and reforestation with short (RSR) and long rotation (RLR), and reforestation without rotation using fast (RFG) and slow growing species (RLG) which fall under category two. The option of fossil fuel substitution was not evaluated in this study due to a lack of data.

2.4.3.1. Methodology for Mitigation Assessment

The assessment of mitigation option was carried out using COMAP (Comprehensive Mitigation Analysis Process model). COMAP was developed by the Lawrence Berkeley National Laboratory (LBNL), USA to guide an analyst undertaking a comprehensive assessment of GHG mitigation efforts for land use change and the forest sector (Callaway et al., 1999).
As was mentioned previously, five options were evaluated. Planting trees without rotation is intended for conservation, which is designated for rehabilitating critical areas of forest. Forest protection is intended for protecting forests from conversion to other uses and from harvesting, while planting trees with rotation is intended for reforesting degraded forests or non-productive forests and for producing wood. Data inputs were obtained from official or non-official reports and published references. Cost data were mostly taken from the proposed budget for the 2000 reforestation program issued by the office of reforestation, except for RSR, which was obtained through interviews with foresters at the DFW. It was indicated that the investment, and first year operation and maintenance cost for RSR were higher than RLR. The investment cost of RSR is US$ 400 per ha, while RLR was US$ 300 per ha, and the first year operation and maintenance cost for RSR was US$60 per hectare and US$ 12 per ha for RLR.

The analysis of land allocation for each option were based on the 2000 Reforestation Planning Program, proposed by the Office of Reforestation, and the Five-Year Plan for Forestry Sector,2001-2002) prepared by the Department of Forestry and Wildlife, and the Ministry of Agriculture, Forestry and Fisheries. The plan states that 6 million hectares of degraded forestlands need to be rehabilitated between 2001 and 2005. Percent allocation for RSR, RLR, RFG and RLG were 51, 19, 22, and 8%, respectively.

2.4.3.2. Potential and Cost Effectiveness of Mitigation Options

Mitigation potential of the five options ranged from 43 to 141 tC/ha. RLG and FP have mitigation potential of more than 100 tC/ha, while the other three have less than 100 tC/ha (Table1.3). In terms of investment cost, FP is the lowest (2.5US$/ha), while RSR is the highest (47US$/ha). Life cycle cost for sequestered carbon ranged from 0.28 US$/tC to 1.78US$/tC, while the net present value of benefit ranges from –0.77 to 4.66 US$/tC. Options that gave positive benefits were only RLR and RSR (from harvested wood). The others options gave negative benefits since no wood harvesting is allowed. Costs of carbon abatement of this study were slightly lower than the mean global cost. For low latitude regions, mean global cost for carbon abatement was between 2 and 7 US$/tC (Table 9).

Table 9 Comparison of the Five Mitigation Options

Mitigation Option	**Mitigation Potential (tC/ha)**	**Initial Cost**		**PV of Cost**		**NPV of Benefit**	
		$/tC	**$/ha**	**$/tC**	**$/ha**	**$/tC**	**$/ha**
RLR	120	0.29	35.4	0.41	48.8	0.05	6.0
RSR	43	1.10	47.2	1.78	76.2	4.66	199.8
RLG	141	0.18	25.4	0.28	39.2	-0.26	-36.4
RFG	92	0.28	25.4	0.43	39.2	-0.32	-29.1
FP	137	0.02	2.5	0.51	70.0	-0.77	-105.7

2.4.3.3. Mitigation Scenarios (Baseline, potential and mitigation)

In this study, three mitigation scenarios were proposed namely baseline scenario, potential scenario and mitigation scenario.

The baseline scenario is a scenario to evaluate mitigation potential of LUCF sector in the future if the rate of tree planting (sink enhancement) on degraded land is assumed to be the same as the historical planting rate and no efforts are made to protect the protection forest from being deforested.

The mitigation scenario is a scenario to evaluate mitigation potential of LUCF sector in the future if the rate of tree planting (sink enhancement) and efforts to protect the forest from deforestation follow government plans.

The potential scenario is a scenario to evaluate mitigation potential of LUCF sector in the future if all degraded land were reforested and efforts to protect the forest from deforestation were maximum.

Table 10 Global Potential and Costs (1995-2050)

Latitudinal Zone	Measure	CS equestered (GtC)	Cost (US$/tC)	Total Cost (10^9US$)
High	Forestation	2.4	8 (3-27)	17
Mid	Forestation Agroforestry	11.8 0.7	6(1-29) 5	60 3
Low	Forestation Agroforestry Regeneration Slowing deforestation	16.4 6.3 11.5-28.7 10.8-20.8	7(3-26) 5(2-12) 2(1-2) 2(0.5-15)	97 27 44-97
	Total	**60-87**	**3.7-4.6(1-29)**	**250-300**

Source: Sathaye (1999).

Using the above assumption, under the baseline scenario, the total area that could be reforested in the next 30 years is approximately 16,320 ha based on the historical rate of reforestation of 544 ha/year (DFW. Statistics of Reforestation). Under the mitigation scenario, the total area that should be reforested is approximately 2 million ha since in the Second Five-Year Plan for the Forestry Sector (DFW), it was stated that the government target for reforestation was only 33% of the total degraded forestlands. The total degraded forest was estimated to be approximately 6 Million ha. Total area of protection forest that can be protected from deforestation is Approximately 33,791 ha. Under the potential scenario, the total area that should be reforested is 6 million ha and deforestation prevented should be approximately 70,182 ha. Figures for avoided deforestation in mitigation and potential scenarios were taken from Cambodia Forest Policy Assessment developed by World Bank/FAO/UNDP (1996; see Appendix 1.4 under Scenarios 2 and 3). Avoided deforestation of approximately 70,182 ha can be achieved under strict forest management policy. The total area allocated for the three scenarios as well as total carbon mitigation potential, investment cost, life cycle cost and net present value of benefit is presented in Table 12.

Table 11: Mitigation Potential, Investment Cost, Present Value of Cost and Net present Value of Benefit of the 3 Scenarios

Mitigation Option	Mitigation Potential (t C/ha)	Land Available (ha)	Carbon Mitigation (t C)	Investment Cost (US$)	PV of cost (US$)	NPV of Benefit(US$)
Scenario1: Baseline						
RLR	120	3,084	369,954	109,088	150,545	18,674
RSR	43	8,340	357,526	393,256	635,808	1,666,456
RLG	141	1,322	186,060	33,506	51,888	-48,063
RFG	92	3,574	328,815	90,589	140,291	-103,962
Total		**16,320**	**1,242,356**	**626,439**	**978,532**	**1,533,104**
Scenario2: Mitigation						
RLR	120	374,900	44,965,788	13,259,030	18,297,835	2,269,700
RSR	43	1,013,620	43,455,139	47,797,983	77,278,771	202,547,952
RLG	141	160,672	22,614,528	4,072,416	6,306,719	-5,841,834
RFG	92	434,408	39,965,573	11,010,607	17,051,500	-12,635,993
FP	137	33,791	4,626,933	84,478	2,366,742	-3,570,247
Total		**2,017,391**	**155,627,961**	**76,224,514**	**121,301,567**	**182,769,578**

Scenario3: Potential						
RLR	120	1,134,000	136,012,669	40,105,958	55,347,353	6,865,396
RSR	43	3,066,000	131,443,253	144,579,501	233,753,089	612,667,730
RLG	141	486,000	68,404,500	12,318,258	19,076,585	-17,670,398
RFG	92	1,314,000	120,888,000	33,304,921	51,577,434	-38,221,395
FP	137	70,182	9,609,823	175,455	4,915,561	-7,415,157
Total		**6,070,182**	**466,358,244**		**364,670,022**	**556,226,175**

Based on the data from Table 12, it can be estimated that total carbon that can be abated under the baseline, mitigation and potential scenarios are approximately 1.24, 155.6 and 466.4 million tonnes carbon respectively, while the cumulative investment required are approximately 0.63,76.22, and 230.48 million US$ and the life cycle costs are approximately 0.98, 121.30 and 364.67 Million US$, respectively and cumulative net present value of benefit are approximately 1.53, 182.77 and 556.23 million US$, respectively.

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Building Future Expertise in Climate Change Research for Agricultural Universities and Institutions in Cambodia

MODULE III:

CLIMATE CHANGE AND WATER RESOURCE MANAGEMENT

December, 2021

Introduction to the Training Manual

<u>Background and Aims of Training:</u> This training manual supported a 4-day training on **"Promoting Awareness and Capacity to Climate Change Adaptation at selected provinces and cities in the Mekong Catchment of Cambodia"**. The development of a training manual and the training of trainer program on water resources and climate change is the critical to achieving the objectives of the training in building capacity to adapt to climate change.

<u>Purpose of this Training Manual:</u> This training manual seeks to provide knowledge of and training in Climate Change and Water Resource Management. In this context the trainee will learn the current water management in Cambodia, type of Irrigation, water efficiency, challenging in irrigation, and rain water technique to deal with climate change.

<u>How the training materiel was developed:</u> There are many sources for developing this manual. Internet is the major source including www.who.org and www.oaresciences.org which is the international Journals for best matching literature review. However, since the scope of this manual is mainly demonstrate in the context of Cambodia; it is very important to access the documents from Ministry of Water Resource and Meteorology for documentation and also others research as well.

<u>How to use this manual:</u> This manual can be used for additional documentation for raising-up general knowledge in water resource and climate change. It does really benefit for those who want to know about water resource and climate change and other researches. Before reading this manual please doesn't forget to go through with this Introduction.

Module III: Climate Change and Water Resource Management

The purpose of this training module is to provide trainees in national and sub-national of governmental institutions with KSA (Knowledge, Skills, and Attitude) on climate change and water resource management.

Target Group:

Lecturers, researchers, and staffs in agricultural universities/institutions in Cambodia who interest on climate change.

Learning Outcome:

At the end of the module, the participants will be able to:

1. Understand the concept of water resource management in term of climate change
2. Understand the current water resource management in Cambodia
3. Understand how to design rain water harvesting

Learning Objectives:

1. To provide knowledge on the concept of water resource in term of climate change
2. To provide the trainees to understand the current status of water resource management in Cambodia
3. To provide the trainees the knowledge on how to design rain water harvesting

Content

1. Introduction

Globally, population growth, rising incomes and urbanisation are increasing the demand for water. Each of these drivers of demand is present in the Cambodian context. Cambodia's economy is based largely on the agricultural sector which contributes 33 percent of the national GDP and employs more than 67 percent of the national labour force. The country's population is expected to increase from the current 14.2 million to between 20.4 and 27.4 million by 2050 (UN 2008; ADB 2010a), while simultaneously, the economy is expected to experience a strong record of economic growth. Economic growth between 1998 and 2008 alone averaged 9.1 percent (ADB 2010b) and, against the recent global financial crisis, is estimated to be as high as 6 percent in 2011 (ADB 2010a). Increases in per capita income and urbanisation are also expected (UN 2007), with the resulting rise in the demand for food estimated to be between 109 percent and 206 percent by 2020 compared to year 2000 levels (Hoanh et al. 2003). If this upward trend in demand is to be satisfied by increased domestic agricultural production, a greater strain will be placed on agricultural resources, including water.

Rice production is central to this sector: not only do the majority of Cambodia's farmers depend directly and indirectly on the success of the rice crop each year, but being the main food staple, rice production is a significant factor in the national effort to promote food security. Despite its importance, rice farming in Cambodia has traditionally been dependent on rainfall rather than irrigation, as a result farmers generally only grow one crop per year.

Recognising the importance of water management to promoting the country's rice production, the Royal Government of Cambodia and donors are making efforts to expand the irrigated area in Cambodia. The expectation is that irrigation will make farmers less reliant on rainfall, allowing them to cultivate more crops with more certainty and predictability, resulting in higher productivity and better livelihood outcomes. The government's current planning document emphasises the importance of water management to increase agricultural productivity and stresses 'rehabilitating and enhancing irrigation potential' (Wokker & Santos et al, 2011).

1.1 Current Water Management

In the Mekong region Effective water resource management is crucial from a perspective of sustainable development, economic growth and poverty reduction, and in this sense, it should be seen as a central concern to the Mekong region. Water resources management include the management of resources which directly or indirectly influence the water security of the Mekong region, such as for example the management of forest resources

Moreover, as this book focus specifically on shared water resources, in the shape of water security in the Mekong region, it will naturally also emphasize regional cooperation, the existence of reciprocal trust and data transparency when discussing regional Southeast Asian water resources management.

1.1.1 Current Water Resource Management in Cambodia

1.1.1.1 Managing Forest Resources

Before hostilities plagued Cambodian its land was to 70 percent covered in forest. As of 2009 only 56.7 percent of forest covered land remains. Much of the existing forest resources furthermore remain devastated because of previous conflicts which has left large parts unattended. Moreover, soil erosion due to miss management of forest resources, has had serious repercussions for the Tonle Sap which has become notably shallower. This has already been estimated to have serious implications on fishery resources although further research is needed on the subject.

1.1.1.2 Managing Population Growth

Cambodia's population growth was in 2009 estimated at around 1,7 percent and is expected to rise. As it does, further pressure will be put on the capacity to meet national demands for water resources. As Cambodia remains limited in its capacity to mitigate and handle population growth, especially in terms of urbanization, population growth could very much prove to pose as a serious threat to water security in Cambodia.

1.1.1.3 Managing Climate Change

The predicted climate changes are estimated to have regional implications it is clear that Cambodia will be affected by these changes. Due to the national context and setting of prevalent poverty, many countries remain highly exposed to small changes within the climate, and Cambodia is no exception. In more specific terms, climate change is estimated to increase the annual temperature in Cambodia by 0.7 to 2.7 degrees Celsius by the year of 2060 and with 1.4 to 4.3 degrees Celsius by 2090. Moreover, there will be a substantial increase in the frequency of days which are considered hot while the annual average rainfall is expected to increase. As seen in table 5, climate changes are predicted to increase the agricultural productivity in the area of Northeast Cambodia, Se San, and in Central Cambodia in Kratie and the area of the Tonle Sap. The border shared between Cambodia and South Vietnam will be subject to a predicted decrease.

Table 1: The summery of consecquences of Climate change in Cambodia

	Se San: Northeast Cambodia	Kratie: Central Cambodia	Tonle Sap: Central Cambodia	Phnom Penh: Southeast Cambodia	Border, Cambodia-SouthViet Nam
Agricultural Productivity	+	+	+		-
Existing food Availability	-1	-1	-1	-1	-2
Temperature	+	+	+	+	+
Annual Precipitation	+	+	+	+	+
Dry Season Precipitation	–	–	–	–	–
Annual Runoff	+	+	+	+	+

Dry Season Runoff	–	–	–	+	–
Annual Water Stress					
Dry Season Water Stress					
Flooding Potential	+	+	+	+	+
Peak Flows		+			
Flood Duration		+	+		
Flood Area		+	+	+	+
Dry season minimum flows		+			
Saline intrusion					

Simultaneously, and in accordance with predictions made on a regional level, the existing food availability will decrease in all areas within Cambodia. In the area of the Cambodian and Vietnam border, this will be due to an increase in population growth, while the other areas will be faced with a decrease in surplus. Again in accordance with regional projections, an increase in temperature will occur, which will affect all areas of Cambodia. Annual precipitation is predicted to increase while the duration of the dry season is estimated to decrease, leaving central agricultural areas vulnerable to flooding and drought.

Although the dry season is estimated to decrease, the severity of draught has been predicted to increase. An increase in draught would be a crucial future issue from a perspective of human security in Cambodia, as the Tonle Sap for example provides the Cambodian people with 70 percent of their protein intake. Changes in the current life cycle of fisheries, but also the hydrological cycle of the Mekong River, could thus have devastating repercussions from a perspective of human and food security. As seen in table 5, estimates for annual flooding are unavailable. The potential for flooding has, however, been estimated to increase in all parts of Cambodia while the area of Kratie and Tonle Sap will be faced with an increase in the duration of flooding. As flooding however also provides Cambodia with many benefits, as it directly influences the lifecycle of fisheries, it is an important factor from an economic perspective. A problem however occurs when estimated flooding and draught increase in severity and/or duration. In Cambodia, the Mekong River has historically been observed to flood in a steady and slow manner, with a minimum amount of loss of lives. This is expected to change as the temperature increases due to changes in the climate. As an example, the flood damage and losses resulting from the cyclone Ketsana in 2009 is estimated to have incurred economical costs of 132 million US$ in Cambodia, with some 8.9 million US$ spent on recovery expenses, and when seen in the context of how flooding might increase due to an increase in temperature, it is clear that this could cause catastrophic results for Cambodia as a nation. Due to the possibility of food shortage and as a part of its Initial National Communication, Cambodia has conducted a vulnerability and adaptation assessment, which examines the impacts of climate change on issues of flooding and draught, and its influence on agriculture, forestry and human security. Agricultural assessment was conducted with a focus on rice cultivation which, as mentioned above, remains Cambodia's main source of food security.

Rice production loss between the years of 1996 to 2001 was estimated at 70 percent due to severe flooding. Draught caused a loss equivalent to 20 percent. The assessment also displayed how flooding and draught, although experienced on an annual basis, cause social and economical unrest, as adaptive capacity remains very low. Exacerbated by future climate change, flooding and draught might generate overwhelming consequences for Cambodia as a nation.

Severe flooding also introduces new issues which will need to be handled, such as health hazards. For example, as the population of Phnom Penh grows larger, the disposal of garbage and waste into the Tonle Sap is estimated to increase. When flooded, in combination with an inadequate sewage system, this pollution poses as a threat to the hygiene of the Cambodian people. The spread of disease is, as such, another repercussion from climate change which threatens human security in Cambodia. When summarizing it is clear that Cambodia remains sensitive and vulnerable to any negative changes imposed by climate change as there is a high dependency on natural resources, such as water or fisheries, for the realization of the Cambodian livelihoods human security.

Absence of human security might in turn trigger economic insecurity, or vice versa, and issues of severe flooding and draught, cross-border migration, changes in patterns of economic activities, food security and changes in living environment are all issues of concern in Cambodia that are tightly connected to water security.

1.1.1.4 Managing Water Quality in Cambodia

As mentioned above, the Mekong River remains crucial for the daily survival of the Cambodian livelihoods. A decrease in the water quality of the Mekong River is thus an alarming issue from a Cambodian perspective. There is currently no functioning mechanism available which can measure water pollution exclusively in Cambodia, and as such, it is difficult to predict the exact repercussion of water pollution. Being a part of the LMB, however, some of the studies carried out by the MRC in terms of the WQMN project, cover Cambodian waters. The statistics provided by the Water Quality Monitoring Network paint a bleak picture where human impact around the area of Phnom Penh has caused the river to be severely impacted. Future research is however needed to assess the situation of the water quality in Cambodia.

1.1.1.5 Managing the Construction of Dams and Hydropower Development

The negative effects which dams are likely to have upon the Mekong River has been estimated to hit the area of the LMB particularly hard. While energy accordingly is needed to support the industrialization of the Mekong region, Cambodia also remains highly vulnerable to the negative repercussions which the construction of dams might inflict. As mentioned above, the construction of the Xayaburi dam has raised serious concerns in terms of possible impact on the countries of the Mekong region. If the dam would be deemed to have a negative influence on fisheries and the environment of the Mekong, it is likely that this would have a severe impact on Cambodia. The development of hydropower must therefore take factors like these into consideration so that the development of Cambodia is not further hampered. Additionally it can be noted that the hydroelectricity generating capacity of Cambodia is stated to be more limited than its neighbours, where the northeast and southwest part of the country provides the most favour able setting for dam construction. Areas south of Battambang and on the rivers flowing into the Great Lake, such as Stung Chinit, also hold some potential in terms of hydropower. Most projects are, perhaps for natural reasons, aimed at supporting irrigation while power generation is considered secondary (Maria Larsson, 2011).

1.1.2 Water Resources related to Variability and Climate Change situation

1.1.2.1 Climatic Information

The dominant features of Cambodia landscape are defined by the large, almost centrally located Tonle Sap (Great Lake), the Bassac River, and the Mekong river systems across the country from north to south. Surrounding the Central Plains, which cover three quarter of the country area, there are Elephant Mountains and Cardamom Mountains of southwest and western regions; Dangrek Mountain of the north adjoining the Korat Plateau of Thailand; and the northeast Plateau of Ratanakiri and Chhlong Highlands on the east merging with the Central Highlands of Vietnam.

Like in many countries in the Southeast Asia region, Cambodia climate is dominated by monsoon, which is known as tropical wet and dry climates. The monsoon brings rain to Cambodia during May to September or early October – called wet season; and northeast monsoon blows during November- March bringing dry-cool air; and hotter localized air during late March - late April.

Temperatures are fairly uniform throughout the Mekong River Basin with only small variations from the average annual mean of a round 28oC and the average maximum and minimum temperatures of 34oC and 21o C, respectively (2004).The coldest temperature can be as low as 10o C during the month of January. The warmest month is in April during which the temperature can be as high as 38oC before the rainy season arrives. Normally, typhoons and tropical storms hit hard the Vietnam bays leave less damage on Cambodia areas.

The average of precipitation rate in Cambodia for the recent 11 years (1994 – 2004) is estimated to 1,598.4 mm. The average annual rainfall on the Tonle Sap Basin and the lowlands near Mekong River is estimated of 1,300 to 1,900 mm.

Table 2.1: Variability temperature (Unit in Degree Celsius, o C) throughout the year

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average temperature
Maximum	34.5	35.4	37.2	38.0	37.1	35.7	34.9	34.5	34.2	33.8	34.8	33.4	34.0
Minimum	18	18.1	21.9	21.9	23.1	22.5	22.9	22.7	22.8	21.9	20.1	18.0	21.2

Source: Statistical Year Book, 2005, cited in MOWRAM, 2008

1.1.2.2 Water Resources

Surface water or runoff water is defined as the amount of water that flows into rivers remaining from the processes of evaporation, transpiration, infiltration, and percolation. Surface water sourcing from rain water flows down to Tonle Sap Lake and Mekong River before further down to Mekong Delta and South China Sea. Surface water plays vital role in Cambodia agriculture and economic development.

Ground water: The applications of groundwater as irrigation water are limited to small-scale vegetable gardens, fruit farms or such in the dry season. While groundwater has been developed and used as irrigation water in the southern and eastern areas of Cambodia, the groundwater has been scarcely used in the northwestern areas of the country. MOWRAM (2008) reported that irrigated farmlands accounted for about 20% of the entire cultivated lands, and the farmlands irrigated by surface water and by groundwater accounted for 31.2% and 68.8%, respectively of the entire irrigated farmlands.

Uses of water and development: Total amount of water resources in Cambodia is 289.4 billion m3 and average runoff is 45%, considering the average annual rainfall of 1,598.4 mm, and the land area of 181,086mk2. Total uses of water of all purposes were amounted to 7.9 billion m3 (table 2.2). The consumed water for agriculture is estimated about 7.59 billion m3 (96% of total use), for domestic use is 0.24 billion m3 (3% of total use) and for the industrial use is 0.07 billion m3 (1% of total use).

Table 2.2: Annual water use (2005)

Use of water	Domestic purpose	Industrial purpose	Agriculture purpose	Total
Amount, million m3per year	235.9	71.4	7,586.7	7,894.0

Source: MOWRAM, 2008 p 4-31

Coastal and marine water: Cambodia lies on 440km coastline from northwest to southwest areas within the provinces of Koh Kong, Sihanouk, Kampot and Kep. These provinces are increasingly populated due to economic and tourism development. The areas, especially in the offshore areas, can have much more development activities in the short future because of the exploitation of oil and gas productions.

Concerns: There is growing concern at the likely impact of agrochemicals, particularly of pesticides on fisheries, although data are lacking on the actual quantities of chemical use or of the consequences for water quality. There is less concern about the effects of industrial effluent, because of limited industrial activity until recently. However, future development, principally around Phnom Penh and particularly in the garment industry, could be expected to present growing problems and the environmental impact and monitoring provisions of environmental legislation will become increasingly important. Bacteriological contamination is of greater concern from a public health point of view, with Cambodia “high levels of morbidity and mortality from diseases that often are water-related. Bacteriological quality of Mekong/Bassac waters deteriorates from Phnom Penh, although particularly so downstream from Vietnamese border, across the densely populated delta.

Most Cambodian people face a shortage of freshwater during the dry season, and also during the "small dry season" in the wet season, but in the rainy season face too much water: flood. Irrigation infrastructure is insufficient, old and run-down, which has a severe impact on water storage, distribution and supply, sanitation, and food production. The waters of the Gulf of Thailand are enclosed by land, and there is a growing risk that contaminants and sediment from coastal towns, agricultural areas, and forest logging may pollute the sea. Furthermore, shipping and off-shore exploration for oil and gas reserves present additional risks to the water resources. The Kingdom's marine waters require careful management, particularly along the coastline and in estuaries, to ensure that they continue to support healthy ecosystems and fisheries, and provide the basis for sustainable economic activities, particularly fishing and tourism.

River transport, particularly of petroleum products, to the port of Phnom Penh presents a threat to water quality in the Mekong and it distributaries through the delta. Apart from the unpredictable risk of a major accidental oil spill, there is likely to be more or less continuous leakage and spillage of fuel and cargo, and contamination from ballast tanks etc. The growing use of outboard motors by other river users also presents a pervasive threat to surface water quality, through spillage, leakage etc. No data are available on contamination by hydrocarbons.

Surface water quality in rivers raining from catchments underlain by metalliferous rocks is in some cases degraded naturally. There are locally high concentrations of toxic metals in stream flow from areas in which mining is undertaken. The degree of contamination of surface water by human activity is difficult to quantify. Non-point source contamination by domestic animals and people presumably is widespread in settled areas, because of uncontrolled waste disposal and, to a lesser extent, fertilizer applications. However, loadings per person or stock unit are rather low, and data for nutrient concentrations in the Mekong mainstream indicate low average and maximum values (PO4-P 0.03mg/l, total-P 0.08 mg/l, NH4 –N 0.1 mg/l, total-N 0.5 mg/l, NO3-N in the range 0.1-0.4 mg/l) (MOWRAM, 2000).

The most concerned issue of groundwater quality is arsenic content. There are many wells exceeding the WHO (World Health Organization) guideline in arsenic content, and it is known that this is caused by natural reason, not by human induced activities. Increase of arsenic contents in groundwater affects surface water quality as well.

Floods

Floods normally occur in Cambodia 42 river basins especially in the Mekong and Tonle Sap basins. Two types of floods occur in these are: flash and long-month (3-4month) floods. Flash flood occurs during rainy season, especially within the slop areas of the Cambodia plateau whereas long-month flood normally occurs along the river basins of the Mekong, Tonle Sap and their tributaries. According to historical records, a serious flood happens in the Mekong Delta in more or less of every 4 to 6 years. The serious floods result in really damage agricultural productions, human, and properties. Since the 1960s there have been more than seven serious floods in Cambodia. Flood is one of the most serious problems in Cambodia, while it affects on the country in both positive and negative manners.

On the bright side, seasonal floods play important role in the increase of fishery production, maintenance of ecological environment in marsh, improvement of land productivity by supplying silt sediment, and agriculture water supply. Floodplains are essential to fish hatching areas and fish habitats. Large fishes lay eggs on the bushes inundated by floods. Floodplains are closely related to farming providing a field for seeding, floating rice and flooded rice crop. Mostly rice crop rotation is conducted by farming rice floating in deep water depth of the floodplains.

On the dark side, severe floods make damages on infrastructures, interruption of economic activities, losses of human lives as well as livestock and farm products. When a huge flood came in 2000, about 370,000 ha of farmland were inundated, and 6,081 houses were destroyed affecting people lives of 3.44 million in 132 districts. The estimated amount of flood damage during 1900 and 2012are shown in table 2.3.

It has been noted that flood status has changed for the last few decades, and 3 types of floods identified: i) the increase of flood numbers in the Mekong River more than expected, ii) Heavy rain on the Mekong tributaries, and iii) the increase in flood level.

1.1.2.3 Droughts

The most recent droughts occurred in 1992, 1993, 1998, and 1999. The drought of the 1999 was the most severe that occurred across the country. The impact of drought have similarly been addressed by a number of programs with aiming to improving the irrigation system, rehabilitation of pumping stations and water pump, water supply and sanitation and establishment of Farmer Water User Community (FWUC). For example, MOWRAM's objective for 2001-2005 have been achieved a total of 290 irrigation rehabilitation projects, covering 532,673 ha of wet season rice and 154,368 ha of dry season rice, at a total cost of about US$ 607 million (see also table 2.3). Up to 2003, 315 irrigation projects had been implemented, covering 153,149 ha of paddy rice, of which 89,383 ha for wet season and 63,766 ha for dry season (MOWRAM, 2003).

Sorted by Number of Killed				Sorted by Number of total affected people			Sorted by economic damage cost		
No	Disaster	Date	No.Killed	Disaster	Date	No.Total Affected	Disaster	Date	Damage (US$)
1	Flood	1994	506	Drought	1994	5,000,000	Flood	2000	160,000,000
2	Epidemic	1998	475	Flood	2000	3,448,053	Flood	1991	150,000,000
3	Flood	2000	347	Flood	2001	1,669,182	Drought	1994	100,000,000
4	Flood	2011	207	Flood	2002	1,470,000	Flood	2011	95,000,000
5	Epidemic	2007	182	Flood	2011	1,350,000	Flood	2010	70,000,000
6	Flood	1991	100	Flood	1996	1,300,000	Drought	2002	38,000,000
7	Flood	1996	59	Flood	1991	900,000	Flood	2001	15,000,000
8	Epidemic	1999	56	Drought	2002	650,000	Flood	1996	1,500,000
9	Flood	2001	56	Drought	2005	600,000	Flood	2007	1,000,000
10	Epidemic	1992	50	Flood	1999	535,904	Flood	1999	500,000

Table 2.3: Top 10 Natural Disaster in Cambodia for the period of 1900 to 2012 (source: www.emdat.net)

1.1.3 Climate Change Strategic Plan for Water Resources

1.1.3.1 The Strategy Framework for water resources

Responding to the urgent need for climate change issues and impact, Cambodia ratified the UNFCCC in 1995 and launched the first climate change project to help prepare the Cambodia's Initial National Communication (UNDP/GEF) in 1999. In 2002, Cambodia has acceded to the Kyoto Protocol. The National Climate Change Committee (NCCC), which was established by sub-decree in April 2006 with the representative of 19 Government ministries and agencies, serves as a policy-making body and coordinates the development and implementation of policies, plans and measures to address climate change issues within the country. Recently, the Ministry of Women

Affairs has been included into this Committee. Being as one of the Vice-chair Ministry (figure 4.4), MOWRAM has played crucial roles in the NCCC coordination and policy development such as National Adaptation of Action for Climate Change (NAPA) and especially in development of Cambodia climate change position for the annual UNFCCC conference. The NAPA also identified water resources management and development is one of the 20 priority items, which determines MOWRAM in important position for Cambodia to develop policies to address climate change issues.

The framework CC for water resources management and meteorology is laid out as: sustainable uses of natural water resources, equitable sharing, decentralized water resources management, good governance, and sufficient irrigation systems. The framework is detailed in the points of: Priority Water Resources and Irrigation climate change related issues; Water-Climate Change Impacts and Opportunities; Water-Climate Change Strategy; Water-Climate Change Roadmap and Implementation Plan; Water-Climate Change Adaptation Strategy; Water-Climate Change Mitigation Strategy; Water-Climate Change Cross-Sectoral Issues at national and sub-national levels; Key Water-Climate Change Response Activities and Risks; Financial Resource Planning; and List of Climate Change Response Activities.

1.1.3.2 Priority Water Resources and Irrigation climate change-related issues

In water resources management and development in Cambodia, there are barriers related to capacity for climate change adaptation that highlighted to be addressed as followings:

a) Limited financial resources or funding for water resources-climate change related activities, especially in the irrigation systems for agriculture sectors;
b) Few water resources-climate change studies and little experience within the country;
c) Lack of sustainable water resources management and development research in response to climate change and/or training institutions in the country;
d) Lack of data availability and reliability and, in particular, absence of a formal mechanism for water resources-climate change information sharing;
e) Limited cooperation and coordination among institutional agencies related to research or studies on water resources-climate change and climate variability;
f) Relatively low technical capacity of officials at both national and sub-national levels;
g) Relatively low government salary and limited incentives from the climate change project;
h) Incomprehensive national climate change policies and/or strategy;
i) Lack of qualified national experts in the country;
j) Limited public awareness and education on water resources-climate change; and
k) Limited technical, financial and institutional resources for water resources management and development in climate change adaptation and mitigation.

1.1.3.3 Climate Change Impacts and Opportunities on water resources

- **Climate Change Impact**

The impact of climate change will be an unprecedented and increasing global threat to life, livelihoods and life-supporting systems. Cambodia’s contribution to greenhouse gas emissions is negligible and the country is ranked number 109 by the World Resources Institute, with emissions of only 0.29 ton of carbon dioxide per head of population each year. However, Cambodia will suffer from the effects of global warming due to excessive emissions in other parts of the world.

Like other countries in Southeast Asia, Cambodia is expected to experience higher and more intense rainfall. The effects are likely to include more severe water scarcity and more frequent floods, resulting in crop failures and food shortages. Accelerated loss of biodiversity will cause a decline in ecosystem services. Coastal communities and eco-systems are likely to be affected by rises in sea levels. Higher temperatures and humidity will create conditions for increased incidence of malaria and dengue fever. The poor and marginalized, particularly women and children, will be worst affected.

Recently, Cambodia facing various problems since there are increasing natural resources degradation due to forest, water, land and mineral resources have been overusing for economic development and pro-poor development activities in country-wide up to date. These problems are major for environment which appeared such as higher temperature, precipitation and sea level rise. It is to start a knowledge related to climate change in Cambodia. The simple understanding on climate change, showed by Website chinaview.com, the word “climate change” is a change in the "average weather" that a given region experiences. Average weather includes all the features we associate with the weather such as temperature, wind patterns and precipitation. What Cambodia is more worried about now is the impact of human activities on climate change and the human responses to the changes of climate. The world agreed that CC comes from human activities, releasing greenhouse gases (GHG) into the atmosphere. Carbon dioxide (CO2) is produced when fossil fuels are used to generate energy or when forests are cut down and burned. Methane (CH4) and nitrous oxide (N2O) are emitted in many ways for example agricultural activities, change in land use, and other sources.
The impacts of CC on water works include:

a) Water resources sector: problems of increased frequencies of flood & drought, changes in water supply, water quality, and increased competition for water. The irregular seasonal time of raining and dry months caused by CC especially during the last few decades imposes on water resources management and development efforts. At the same time, the increasing demand of water for emerging sectors including industry, livestock, domestic uses, and especially for agriculture, while season is changing due to CC, creates many more social problems. With the global warming, the Cambodia temperature has increased makes it difficult to prevent water from evaporation and lost. The groundwater, on the other hand, requires recharge annually from rain water. Due to the CC impacts on the amount of rainwater that needed to be recharged to the groundwater, it is seriously reduced the recharge rate; and as the result, Cambodian farmers have insufficient groundwater for their farming activities. It is worth noticed that the groundwater shares 3.1% of the total 4.5% of the current irrigation water while surface water shares the rest (MOWRAM, 2008).
b) Reservoir: Many reservoir have gradually been shallower caused by sedimentation, which leads to reduce capacity of water storage.
c) Irrigation systems and hydraulic infrastructure: It is noted that the irrigation systems and hydraulic infrastructure have not yet been modernized and taken CC into consideration in almost all areas of the country. Floods and droughts impact on irrigation systems and hydraulic infrastructure. Most importantly floods cause tremendous negative impacts on irrigation systems located in the low land areas.
d) Dam/weir: Frequent floods destroy many dams; most of them are old and unrealistically considered on the impacts of CC.

e) Flood Protection Dike (FPD): Most dikes have been destroyed by floods because during each floodwater overflows on these Flood Protection Dikes due to their height are not high enough compared to flood levels. The problem is that CC impacts were not taken into account during the FPD construction. Moreover, these FPDs are made from almost soils.
f) River Bank and Coastal Areas: erosion of beaches/banks caused by floods and/or high speed waves induced by the impacts of unpredictable CC leads to negative impact on rural livelihoods, especially farmers who are completely dependent on limited land areas.

- **Climate Change Opportunities**

Being as Vice-Chair of the National Committee for Climate Change, the MOWRAM has played an important role in water-Climate Change related coordination and facilitation. With the Chair-Ministry, the Ministry of Environment, the MOWRAM has committed itself to address climate change issues in particularly sustainable water development and water good governance. This should be significant opportunity for the mandates of the MOWRAM to implement water-related laws and regulations to achieve the Vision, missions, and objectives of the water resources management and sustainable development in Cambodia. Also, this should be an excellent opportunity for the MOWRAM to fulfill its tasks in sustainable water management and development mainstreaming gender balance in climate change responses.

Due to the global and regional CC, Cambodia has faced with increasing floods and droughts. In this regards, climate change funds should be crucially important additional fund for flood and drought disaster management and prevention. In Cambodia, climate change funds should be used for planned adaptation while at the same time encourage autonomous adaptation that has been implemented for thousands of years in Cambodia and in the Mekong River Basin.

Because climate change is one of the emerging global issues, most of the laws and regulations related to water resources management and meteorology have yet detailed addressing climate change issues. Therefore, it is the right time for Cambodia to include national CC strategic plan in water resources and meteorological management and development.

1.1.3.4 Climate Change Strategy for water resources

Resulting from the importance and barriers of adaptive capacity for climate change in Cambodia, several challenges for adaptive capacity to respond to climate change can be summarized as follows:

i. Awareness and knowledge on climate change related to water resources management and development must be mainstreamed to all water-related sectors development aspect at local, provincial and national levels through media system, TV spots, radio and campaign; (A&M)
ii. Staff capacity building on water resources-climate change through long term-studies, short course trainings and exchange study tours in and out of the country and the region.
iii. Establishment of data management system for collecting and sharing data and information on water resources related climate change issue and adaptation/ mitigation capacity to related stakeholders; (A&M)
iv. Establishment and or improvement of networks for meteorology and hydrology to manage and control for example temperature, rainfall, flood, drought and weather impacted by climate change; (A)

v. Mobilization of secured financial resources for programs/projects, research and development on water resources-climate change adaptation or mitigation from both the government agencies and development partners; (A&M)
vi. The appropriate capacity of local farmers, especially FWUC members, on the selection of less-water-crop varieties, and the planning of less-water-crop system for climate change adaptation. (A&M)
vii. Development of long-term water resources integrated planning of providing best chance of minimizing the sea-level rise's negative effects; (M)
viii. Strengthening the cooperation and coordination mechanism among different sectors agencies at local, national, regional and international level applying IWRM aspects to response the climate change adaptation and/or mitigation; (A&M)
ix. Improve and introduce high technologies in water work development in order to respond to the negative impacts of CC. (A)

1.1.3.5 Climate Change Roadmap and Implementation Plan for water resources

Aligning with the government National Strategic Development Plan (2009 – 2013), the MOWRAM set its strategic roadmap for water resources climate change-related management and development plan as followings:

1. Capacity building for staff and farmer/publics on CC adaptation/mitigation in regards to water resource development and management.
2. Mobilize high technology and financial resources for water resources and meteorology development in highly responding to CC impacts.
3. Data management in regards to water resources and meteorology for timely CC responses.
4. Develop integrated long-term water resources and meteorology countrywide plans for CC adaptation and mitigation.
5. Establish national policy and legislations in an emerging needed CC responded for water resources and meteorology management.
6. Strengthen inter-ministerial coordination in the framework of CC adaptation and mitigation.

Gender mainstreaming in water resources management and development is one of the most important targets of the MOWRAM. A gender balance in water resources and meteorological management is firmly implemented as followings:

- Improve gender balance in water resources management through capacity building;
- Create opportunities for women in socio-economic and political participation;
- Mainstream gender balance and supports for both national and sub-national levels;
- Engage women in capacity building through on-the-job training in office and in abroad;
- Ensure that water resources related-services benefit to women especially in the FWUC.

1.1.3.6 Water Resources-Climate Change Adaptation Strategy

Based on previous excellent achievement such as improvement of the irrigation system, rehabilitation of pumping stations and water pump, water supply and sanitation and establishment of Farmer Water User Community, the water-climate change adaptation strategy should be included for future plans. As the Master Plan of Water Resources Development in Cambodia has been developed with very detail and specific management plans for many chapters of water schemes (MOWRAM, 2008), our water-climate change adaptation strategy should be focusing on main adaptive strategies and activities as followings:

i. Awareness and knowledge on climate change related to water resources management and development must be mainstreamed to all water-related sectors development aspect at local, provincial and national levels through media system, TV spots, radio and campaign. The detail activities are as followings:
    - To strengthen and extend the hydrological and meteorological systems including data collection and dissemination;
    - To provide short, medium and long-term forecasts and warnings of droughts, floods and storms to the public and related institutions;
    - To improve the existing and install new hydrological and meteorological stations and staff/rain gauges in the selected rivers and locations including data collection and dissemination;
    - To establish hydrological observing system that provides real-time water level and flow data for forecasting purposes, and hydrological data for design of water resources projects, water resources management, and other purposes;
    - To install a meteorological observing system that provides real-time weather data for forecasting purposes, and climatological data for agro-meteorology, design and other purposes;
    - To provide public weather forecasts and warnings, and inform and educate the public about climate, climate variability, and climate change;

ii. Staff capacity building on water resources-climate change through long term-studies, short course trainings and exchange study tours in and out of the country and the region.
    - To expand the surface water storage (reservoirs, ponds), channel capacities and drainage systems to ensure water supply and environmental sustainability way;
    - To extend the land area served by sustainable irrigation and/or drainage systems, particularly in areas with a high incidence of poverty;
    - To strengthen the technical and institutional capacity of MOWRAM to implement the I&D strategy;
    - To focus management effort on priority river basins and to conserve the ability of groundwater aquifers;
    - development and management plans;
    - To establish the capacity of FWUC's in participatory irrigation management and development (PIMD);
    - To facilitate increasing income in the irrigated agriculture sector, to ensure continued investment in water for crop production.

iii. Establishment of data management system for collecting and sharing data and information on water resources related climate change issue and adaptation/mitigation capacity to related stakeholders. The detail activities are as followings:
    - Timely collect data on water resources-related climate change disaster and possible overcome strategies;
    - Provide open access to data of water resources development and management and meteorology;
    - Based on historical records of water resources and meteorology data, provide and analyze possible CC vulnerability.

- To study, rehabilitate and construct the system of flood protection embankment and drainage in the purpose of the natural disaster reduction related to water;
- To improve and strengthen on weather and flood forecasting in real-term related natural hazards;
- To respond immediately paying an action on pump and heavy equipment intervention, where are suffering and affected by drought, flood, and other water-related hazards;
- To encourage and promote to the people and institutions at all levels participatively in flood mitigation measures and drought intervention;
- To develop and enhance the national groundwater data and information base.

iv. Establishment and or improvement of networks for meteorology and hydrology to manage and control for example temperature, rainfall, flood, drought and weather impacted by climate change. The detail activities are as followings:
   - Provide timely prior warning information and trusted data;
   - Use all means of the meteorology systems to inform all possible risks caused by weather.
   - To strengthen the implementation and enforcement of law on water resources management, sub- decree on water management, irrigation management and transfer and others water related regulations to control and prohibit all construction projects that are impact to the water resources as well as eco-systems;
   - To develop and apply procedures for social and environmental impact assessment and mitigation;
   - To preserve the river flows and minimum water level of rivers, streams, lake for ensuring the ecosystems, social and cultural values, and navigation;
   - To prohibit and take necessary measures to the infilling or excavation of or encroachment on watercourses, seasonally inundated depressions, permanent water bodies, and the sea, where there would not be permitted and would be an impact on water resources, aquatic ecosystems or the environment;
   - To conserve and strengthen the ability of natural lakes to provide flood retention and support aquatic ecosystems;

v. Mobilization of secured financial resources for programs/projects, research and development on water resources-climate change adaptation or mitigation from both the government agencies and development partners. . The detail activities are as followings:
   - Develop financial plan for short, medium and long-term water resources management and development;
   - Mobilize all sources of funding for water resources management and development in response to CC.

vi. The appropriate capacity of local farmers, especially FWUC members, on the selection of less-water-crop varieties, and the planning of less-water-crop system for climate change adaptation. The detail activities are as followings:
   - Conduct research and development (R&D) paying more attentions of CC adapted crop species;
   - Closely engage members of FWUCs in CC adaptive crop species;

- Conduct study tours for selective members of FWUCs in CC adaptation agriculture development.
- To mobilize participation of farmers, stakeholders and the private sector in all stages of design, development and improvement of I&D systems
- To enable FWUC, beneficiary and private sector participation in all stages of the development and management of I&D (PIMD);
- To strengthen and expand Farmer Water User Communities, to enable them to participate in water management and allocation and to maintain irrigation infrastructure with effectiveness and sustainability,
- To promote investment by international funding agencies and the private sector in supporting PIMD;

1.1.3.7 Water Resources-Climate Change Mitigation Strategy

Water ecosystems, such as wetland and marine water, are considered as areas for carbon sequestration and carbon stock. When the water areas such as wetlands changed for other development purposes such as agriculture activities, the carbon stock areas will be lost. In this regards, the climate change mitigation strategy in the water resources management should be to reduce the change of land use as much as possible. As law on water resources management states, the MOWRAM strategy in climate change mitigation should be to strengthen the enforcement of the law as much as possible. At the same time all water resources management regulations have to be strongly implemented. Water resources management and meteorology in regard to CC mitigation can mostly related main mitigation strategies and activities are as followings:

vii. Development of long-term water resources integrated planning of providing best chance of minimizing the sea-level rise’s negative effects. The detail activities are as followings:
    - Prepare strategic plan for prevention methods/means to cope with sea-level rise that could negatively effect on agricultural development;
    - Provide R&D in biofuel and biogas development and utilization to members of FWUCs;
    - Mobilize all means to assist rural publics in biofuel and biogas utilization in order to minimize GHG emission.
    - To prepare a river basin inventory and database.
    - To develop the Nationwide Flood Hazard Map.
    - To study and the preparation of short-, medium-, and long-term development plans for river basins by taking comprehensive account of modifications to the hydrological system, particularly river flows and aquifer levels, to ensure that utilization of water resources at present and in the future is sustainable;
    - To establish the Nationwide Irrigation and water sources Inventory including monitoring system;
    - stakeholders and beneficiaries in, the preparation and implementation of river basin

viii. Strengthening the cooperation and coordination mechanism among different sectors agencies at local, national, regional and international level applying IWRM aspects to response the climate change adaptation and/or mitigation. The detail activities are as followings:
    - Coordinate among ministerial agencies in law enforcement on water resources pollution prevention;
    - Strengthen coordination of all Water Resources and Meteorology line ministry from national to sub-national levels to mitigate impacts from CC.

- To strengthen in cooperation with MRC on Flood Mitigation and international programmes to mitigate related to water hazards.
- To strengthen an integrated approach to water resources and agriculture development and management, that at the same time considers all sources of water, linkages between the water resource and agriculture and other aspects such as land management, natural environment, the varying human and ecological demands on the water resource, and the need for many different disciplines to carry out effective management;
- To promote and facilitate knowledge about, and participation by line agencies,

ix. Introduce high technologies in water work development and rehabilitation in order to respond to the negative impacts of CC. The detail activities are as followings:
  - To rehabilitate and reconstruct the existing irrigation system, in order to response the urgent need the use of water for agricultural production;
  - To develop and extent an appropriate water management technologies that are particularly suited to rain-fed agricultural areas,

1.2 Irrigation

Irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Additionally, irrigation also has a few other uses in crop production, which include protecting plants against frost, suppressing weed growing in grain fields and helping in preventing soil consolidation. In contrast, agriculture that relies only on direct rainfall is referred to as rain-fed or dry land farming. Irrigation systems are also used for dust suppression disposal of sewage, and in mining. Irrigation is often studied together with drainage which is the natural or artificial removal of surface and sub-surface water from a given area (Wikipedia, 2014).

1.3 Reason for Irrigation

Irrigation is the process by which water is brought to dry land through artificial means, such as pipes, hoses or ditches. The land that is being irrigated usually contains crops, grass or vegetation that would not usually receive enough water from rainfall or other natural sources. Sometimes the reason to irrigate a portion of land is that it happens to be a dry season, with less-than-average amounts of rainfall, or it might be necessary to do so because that land never would receive enough water on its own to be fertile. The water that is used for irrigation might be taken from nearby lakes, reservoirs, rivers or wells. The amount of water that is to be used for irrigation depends on the type of crop that is being farmed as well as the amount of rainfall in the region. There are some countries where water is used for irrigating land more than it is used for other purposes. In the US, about one-third of the water that is utilized each year is used for irrigation. Worldwide, it is more than half (Shepley, 2013).

2. Types of Irrigation

2.1.Surface Irrigation

In surface irrigation systems water is moving over the land by simple gravity flow in order to wet it and to infiltrate into the soil. They can be subdivided into furrow, border strip or basin irrigation. (Suhana, 2009). The water supply to an irrigated field has four important characteristics: (1) its quality; (2) its flow rate; (3) its duration; and (4) its frequency of delivery. The quality of the water added to the field will be reflected in the quality of the water throughout the root zone. Salinity is usually the most important quality parameter in surface irrigation and the higher the salinity in the irrigation water, the higher will be the concentration of salts in the lower regions of the root zone. However, since basins do not apply water to the crop canopy as does sprinkle irrigation, water supplies with relatively high salinities can be used some water supplies also have poor quality due to toxic elements like Boron. The most important factor in achieving high basin irrigation uniformity and efficiency while minimizing operational costs is the discharge applied to the field. In basin irrigation, the higher the available discharge the better, constrained only by having such a high flow that erosion occurs near the outlet. The duration of irrigation is dependent on the depth to be applied, the flow rate onto the field, and the efficiency of the irrigation. Basin irrigation's typically high discharges and high efficiencies mean that basin irrigations may require less total time than borders and furrows. This coupled with the fact that basins usually irrigate heavier soils and apply larger depths means that the irrigation of basin is typically less frequent than borders or furrows. The duration and frequency of basin irrigation impose different requirements on the water supply system than systems operated to service border and furrow systems (Shepley, 2013).

The advantages of surface irrigation system are:

- Because it is so widely utilised, local irrigators generally have at least minimal understanding of how to operate and maintain the system
- Surface irrigation systems can be developed at the farm level with minimal capital investment
- The essential structural elements are located at the edges of the fields, which facilitates operation and maintenance activities
- If the topography is not too undulating, these costs are not great
- Energy requirements for surface irrigation systems come from gravity
- Surface irrigation systems are less affected by climatic and water quality characteristics
- The gravity flow system is a highly flexible, relatively easily managed method of irrigation

The Disadvantages of surface irrigation are:

- The soil, which must be used to convey the water over the field, has properties that are highly varied both spatially and temporally
- Surface irrigation systems are typically less efficient in applying water than either sprinkler or trickle systems
- The need to use the field surface as a conveyance and distribution facility requires that fields be well graded if possible
- Surface systems tend to be labour-intensive (Sustainable sanitation and water management)

2.2. Localized Irrigation

Localized irrigation is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods (Suhana, 2009).

2.2.1. Drip or Trickle Irrigation

Today, it is common used all over the world in agricultural, nursery, greenhouse, landscape and variety of industrial applications. In recent years, the demand of drip irrigation has grown rapidly and for good reason the technology can help solve serious problems associated with water use. Many landscapes also enjoyed significant water and capital investment savings using drip, while simultaneously improving plant vigour by delivering water and nutrients directly to the plant roots and avoiding unnecessary wetting to the plant roots and avoiding unnecessary wetting of plant leaves. In addition, drip irrigation allows for targeted, intelligent water applications, where runoff, leaching and the wetting of non-targeted areas such as roads, plant leaves, tree trunks, sidewalks, cars, windows and buildings are avoided or completely eliminated (Irrigation solution). Drip irrigation is the targeted, intelligent application of water, fertilizer, and chemicals that when used properly can provide great benefits such as:

- Increased revenue from increases yields
- Increased revenue from increased quality
- Decreased water costs
- Decreased labor costs
- Decreased Energy costs
- Decreased fertilizer costs
- Decreased pesticide costs
- Improvement Environmental quality (Advantages of Drip Irrigation, 2014).

Disadvantages of drip irrigation presents as following below:

- Expense especially initial cost is high
- The lifetime of the tubes used in irrigation system can be shortened by the sun causing wastage
- May cause clogging if water is not filtered correctly
- Problems in moisture distribution
- Salinity problem
- Germination problem
- High skills are required (Civilengineersforum, 2013).

Drip (trickle) irrigation waters crops efficiently.
Credit: Nova Scotia Agriculture and Fisheries

2.3.Sprinkler Irrigation

Sprinkler Irrigation is a method of applying irrigation water which is similar to rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air and irrigated entire soil surface through spray heads so that it breaks up into small water drops which fall to the ground. Sprinklers provide efficient coverage for small to large areas and are suitable for use on all types of properties. It is also adaptable to nearly all irrigable soils since sprinklers are available in a wide range of discharge capacity. Sprinkler irrigation is suitable for almost all field crops like wheat, gram, pulses as well as vegetables, cotton, soya bean, tea, coffee, and other fodder crops (Sprinkler Irrigation Systems).

The main advantages sprinkler irrigation are:

- Expansive land levelling is not required.
- Water saving irrigation intensity can be changed in accordance with the infiltration capacity of soil.
- High efficiency due to uniform water distribution.
- No special skills trained personal can operate the system reasonably well.
- Ease and uniform application of fertilizers and pesticides through irrigation system.
- Possibility of applying minute quantity of water for germination and other irrigation systems.
- Frequent and light irrigation possible giving better response from the crops.
- Increase in yield and quality, early ripening, 2water conservation and alternative value of specific period saving of labor, machinery, fertilizer and pesticides (Irrigation, 2009).

Disadvantages of sprinkler irrigation are:

- High initial cost
- High operating cost
- Wind drift

- A stable water supply is needed
- Saline water may cause problem
- Water must be free from send, debris and large amount of soil (Civilengineersforum, 2013).

2.4.Sub-Irrigation

Sub-irrigation is a type of irrigation method that provides water to a plant from beneath the soil surface. This type of irrigation is also called "seepage irrigation," and it is often used to grow field crops, tomatoes, peppers, and sugar cane are often watered in this way. In addition, house plants can be maintained using this type of irrigation.

Many plant experts agree that taking care of house plants is easier to do with the help of sub-irrigation. Rather than watering plants from the top, this method allows plant owners to use a self-watering plant system. Creating a small reservoir of water in the bottom of a plant container allows a plant to soak up water as needed. Unlike the above-watering process, watering a plant from the bottom of a container is easier on the plant. When seepage irrigation is used in a field, a field's water table must be manually raised in order for a farmer to feed crops from below the soil line. The water table refers to the level of the groundwater pressure when compared with the atmospheric pressure. Farms that use sub-irrigation techniques often maintain this type of irrigation through pumping station canals, gates, and weirs that lower or raise the water level accordingly (WiseGEEK, 2014).

The advantages of this system are manifold, particularly:

- The high uniformity of water delivery through the use of self-compensating drippers.
- The reduced phenomenon of erosion and washing away. In fact, the low capacity rates of the drippers encourage percolation of water in the soil. Erosion and washing away are further accentuated in largely slope land if irrigated by sprinkling irrigation, thus sub-irrigation systems avoid such consequences.
- The ability to irrigate areas of various shapes and sizes.
- The low - virtually inexistent - exposure to acts of vandalism, a problem particularly acute in parks and public gardens. In fact, the entire system is buried underground and cannot be damaged.

- The respect of the irrigation perimeter and no wetting of walls, sidewalks and any other existing masonry.
- The high flexibility in scheduling the irrigation timetable. During the irrigation process all your green areas can still be used and enjoyed while daytime irrigation cycles operate. Moreover irrigation can be carried safely even in the event of strong winds.
- The possibility to irrigate large areas at one time by using low pressures and capacity rates and relatively small pipes.
- The reduction of plant diseases since the water is delivered directly to the plant roots and not on the leaves or flowers.
- The reduction of the energy used thanks to pumping stations of lower power due to the smaller size of the system.

Finally and most importantly the possibility to integrate to the irrigation a system of fertilization that benefit plants and does not disperse fertilizer in the air or soil (Scarabelli Export).

2.5 Manual Irrigation

These systems have low requirements for infrastructure and technical equipment but need high labor inputs. Irrigation using watering cans is to be found for example in per-urban agriculture around large cities in some African countries. This type of irrigation is also practiced in poor or developing countries. It is also practiced in small gardens (Wikipedia, 2014).

Watering can or bucket irrigation is the simplest form of overhead irrigation and is widely used by smallholder farmers. Although it is very labour intensive the method can give very high water use efficiencies as little water is lost in conveyance from the source to the field and there is fairly precise application of water to individual beds. The method is well suited to irrigate small plots of land, such as vegetable gardens, that are close to the water source, particularly where the water source is very limited or where the recharge of open wells is slow. Where a bucket is used water should be applied to the crop using a simple perforated tin, as shown in Figure 1. Water should not be poured directly from the bucket, particularly when the crop is young, as the small plants may be damaged.

Table 2:Depth of water applied (mm) using watering cans

Number of Watering cans (15 litre)	Bed area		
	1 (m^2)	3 (m^2)	6 (m^2)
1 (15 litre)	15	5	2.5
2 (30 litre)	30	10	5
3 (45 litre)	45	15	7.5
4 (60 litre)	60	20	10

Table 3:Depth of water applied (mm) using buckets

Number of Buckets (20 litre)	Bed area		
	1 (m^2)	3 (m^2)	6 (m^2)
1 (20 litre)	20	7	3
2 (40 litre)	40	13	7
3 (60 litre)	60	20	10
4 (80 litre)	80	27	13

Advantages of the watering can / bucket irrigation method are:

- Cheap to begin and cheap to maintain
- Very portable — very little equipment to be stored or carried from house to field
- Watering cans or buckets are usually locally made
- Very economical on water use (high water efficiency)
- After irrigation, the watering cans or buckets might be used to transport the produce from the field
- Many different types of crops can be irrigated without major changes in the system design
- The best method for irrigating nursery beds

Disadvantages of the watering can / bucket irrigation method are:

- Labor intensive
- Time consuming
- Only a small area, near the water source can be irrigated
- It is risky to draw water from open shallow well or steep rivers, using a can or bucket, when the bank sides are not stable

3. Water Efficiency: Agricultural Irrigation

Agricultural irrigation uses considerable volumes of water, and is one of the largest groups of consumptive water uses in the state. The water efficiency practices listed in this fact sheet describe how to reduce excess water use through implementation of efficient irrigation technology, effective irrigation scheduling and soil moisture determination and retention. These practices are designed to minimize water losses.

3.1. Soil Type Influences Irrigation Strategy

Soil characteristics play an important role in application of soil amendments, pesticides, fertilizers and water. Irrigation strategy for clay-based soils is much different than the strategy for sand-based soils.

When it comes to irrigation, many growers question how much, how long, how fast and how often they need to irrigate. The answers usually involve a combination of soil characteristics, plant growth stage and weather, however, how fast to apply water is based solely on soil type.

Clay-based soils have small, flat, compact particles with large surface to volume ratios. These soils are often difficult to prepare for planting since they are slippery when wet and hard when dry, making timing for field operations critical to avoid damaging soil structure and getting proper soil tilth for planting. Sand-based soils are at the other end of the spectrum having comparatively large particles with small surface to volume ratios. They are generally easier to prepare for planting and can be worked shortly after significant rainfall. There are good and bad points for each soil type (Table 5).

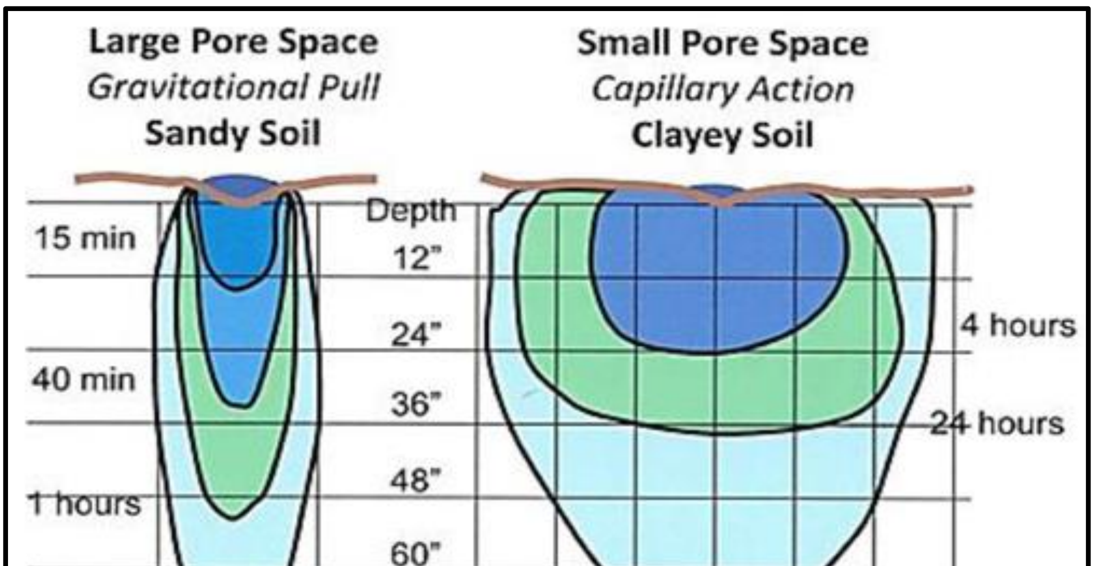
For irrigation purposes, it is important to remember water is absorbed and moves slowly through clay soils, but once wet, they retain significant amounts of moisture. Water is absorbed and moves quickly through sandy soils, but they retain very little. This means water applied quickly to clay soil has a tendency to run off rather than move into the soil. Therefore, when irrigating clay soils, water should be applied slowly over a long period but then the site may not need irrigation for several days. Irrigation on sandy soils should be applied quickly but for short periods. Irrigation times on sandy sites should be shorter, otherwise water moves beyond the root zone, becoming unavailable to the plant and contributing to soil leaching. For efficient water use under certain weather conditions, sandy sites may need daily irrigation for short periods. Clay soils have greater capillary (sideways and upward) movement than do sandy soils (Figure 3). Quick water application on sandy soils will contribute to a broader wetting area, providing more soil volume for roots to exploit

Table 4, Characteristics of sand, silt and clay soils

Property/Behavior	Sand	Silt	Clay
Surface area to volume ratio	Low	Medium	High
Water-holding capacity	Low	Medium to high	High
Ability to store plant nutrients	Poor	Medium to high	High
Nutrient supplying capacity	Low	Medium to high	High
Aeration	Good	Medium	Poor
Internal drainage	High	Slow to medium	Very slow
Organic matter levels	Low	Medium to high	High to medium
Compactability	Low	Medium	High
Suceptibility to wind erosion	Moderate	High	Low
Suceptibility to water erosion	Low	High	Low if aggregated, high if not
Sealing of ponds and dams	Poor	Poor	Good
Pollutant leaching	Poor	Medium	Good

(After Brady and Weil, 2008)

Figure 1, Water spread and penetration time and distance in sandy and clay soils



Michigan soils can vary considerably within the same field. Drip systems can be zoned to account for this variation and each zone irrigated according to the predominant soil type. Emitter flow rate can also be selected to accommodate different soil types; with high flow emitters used on sandy sites and low flow emitters on clay sites. Emitter spacing can also be changed with larger spacing on clay soils and shorter spacing on sandy sites. Growers using drip systems should take advantage of these options to maximize water use while minimizing environmental concern. Overhead irrigators do not have this option, so they need to be more aware of the weather and be sure to not saturate the soil, especially if there is a chance of rain. They also should avoid large applications of water shortly after fertilizer or pesticide applications (Goldy, 2012).

3.2. Understanding the Plants

It is well known that too little water can cause plants to wilt and even die. But over-watering can produce similar problems as the roots rot (a problem to which young plants in pots are very prone). In addition, stress caused by irregular watering can cause some plants to bolt (run to seed) yielding a very poor crop. So supplying the right amount of water is quite an art and is essential to ensuring that you produce a bountiful harvest of fruit and vegetables.

Crops need different levels of water depending on their stages of growth, their position in the garden, the soil type, weather conditions and the variety. Generally, plants need watering more often if they are grown under cover (such as in a row cover or a greenhouse) or if plants are grown in a container (where there is less soil to absorb moisture). People should also consider the position of the plants they grow. In full sunlight, water from the soil's surface will evaporate more quickly than in the shade.

Many vegetables need extra water when in flower or when fruiting. For example legumes (such as beans and peas), sweet potatoes and sweet corn require more water when in flower. Tomatoes and squash plants (such as zucchini and pumpkins) benefit from extra water when their fruit is developing. Peas and beans will develop heavier pods if watered regularly after flowering but too much water early on will result in extra leafy growth and fewer flowers and fruit. Leafy greens and root vegetables require regular watering throughout their growth.

Thirsty crops

The following crops need plenty of water to thrive once fruiting:

- Beans
- Beet
- Carrots
- Cucumbers
- Peas
- Peppers
- Squash (including pumpkins, butternut squash) (Watering and Irrigation).

3.3. Irrigation Management for Water Efficiency

Incorporating a crop demand-dependent irrigation schedule saves water without affecting crop yields. In order to efficiently apply water to the root zone, estimate the water demand based on soil type, precipitation, crop needs and soil moisture retention. The process for developing an irrigation schedule is described below.

- Determine your soil type. Soil characteristics help determine effective irrigation application rates, durations and frequencies. For instance, sandy soils may require more frequent but shorter duration applications.
- Determine weekly precipitation amounts. Install a rain gauge in a central location. Although local radio and TV weather services can give you general precipitation rates for the week, site-specific information is more accurate.
- Determine each crop's water quantity needs. Contact your county cooperative extension service for irrigation demand information for individual crops.
- Monitor soil moisture to determine whether irrigation is necessary. If the soil moisture content is adequate for the crop's water quantity needs, no additional water application is required. Soil moisture can be measured with densitometers, electrical resistance blocks ("gypsum," "ceramic" or "moisture" blocks) or neutron probes.
- Measure the output from your irrigation devices. Use flow meters or gauged water pans to measure the output of sprinklers and drip irrigation heads.
- Combine the five pieces of information above to determine a week-by-week irrigation schedule. Update the schedule as weather and soil moisture conditions change.
- Recheck soil moisture 1-2 days after irrigation to determine depth of applied water and uniformity. If water penetration is too deep, too shallow, or spotty adjust your irrigation schedule to correct it.

3.4. Water Efficiency Practices for Field and Orchard Grown Crops

The majority of agricultural irrigation water in the state is applied to row crops. Water efficiency practices that reduce overhead sprinkler operation can save water and energy costs for vegetable and small fruit farmers. Orchard-grown crops often use very little, if any, applied water, but micro-irrigation methods are easily adapted for orchard-grown crops. The following water efficiency practices can save water in both applications. Space sprinkler heads so that excessive overlap does not occur.

- Choose nozzles that allow for spray pattern adjustments so that water will be applied only to plants, avoiding irrigation between rows.
- Choose low flow, high-pressure nozzles for those crops that can tolerate a higher pressure spray.
- Replace overhead oscillating, center pivot, and walking sprinklers with low-energy precision application (LEPA) or fixed-head types. Moving sprinkler heads broadcast water in all directions, maximizing losses due to wind, evaporation and runoff. LEPA sprinklers work on a center pivot and employ drag hoses and drag socks to position sprinkler heads and apply water near the ground surface. Fixed-head sprinklers can be adjusted to apply water to just the plants and not between the rows.

- Replace sprinkler type irrigation with micro-irrigation wherever possible. Micro-irrigation can be enhanced by using it under plastic mulch.

Retrofit or replace oversized water pumps. Oversized pumps may apply water faster than the soil's infiltration rate, resulting in water loss and soil erosion. The need to maintain the proper pumping pressure leads to over-irrigation if the application rate cannot be controlled

3.5. Additional Practices for Irrigation Water Efficiency

The following miscellaneous water efficiency practices and techniques will help further reduce water use.

- Employ mulches wherever possible.
- Develop an irrigation maintenance program. Routinely inspect all water lines, valves and pumps for leaks. Keep replacement and repair parts on hand. Inspect sprinkler nozzles to ensure they are operating properly and are distributing the water uniformly. Evaluate irrigation system pressures to better control application rates.
- Collect storm water and irrigation runoff in a series of ditches or drains that return the excess water to a storage pond.
- Incorporate moisture retentive polymers in the soil. Though traditionally used in container plantings, these polymers are presently being tested by some growers and golf courses to cut down on irrigation demands.
- Water early in the morning to reduce evaporation losses.
- Practice conservation tillage. Conservation tillage encompasses minimal or no tilling and leaves at least 30 percent of the previous season's crop residue in the field. Although conservation tillage was originally devised to prevent soil erosion, a side benefit is increased soil water storage capabilities.
- Till the land along the topographic contours to reduce runoff.
- Incorporate organic matter such as compost into the soil. Organic matter retains moisture and is especially effective in sand and clay soils.
- Incorporate cover crops for winter and fallow times to improve the soil and reduce water and soil losses caused by runoff. When tilled under, cover crops also add organic matter to the soil.
- Practice deficit irrigation where feasible. This method involves stressing plants by reducing water applications. Be aware that this practice typically reduces crop yields and may lower the quality of some products. However, the water savings may be more valuable than the crop losses.
- Use computer software to aid irrigation scheduling.
- Use pressure regulators for uniform water distribution throughout irrigation systems.
- Use timers, automatic shut off valves, rain sensors and other such devices to help ensure overwatering does not occur.
- Limit the volume of water used for frost protection for late maturing crops such as pumpkins.
- Investigate alternative irrigation water sources, such as treated municipal wastewater treatment plant effluent, treated industrial effluent, on-site gray water systems, and holding tanks for rainwater or greenhouse irrigation water. State and federal regulations that restrict

the reuse of water from certain sources should be investigated and permits obtained where applicable (Environmental Fact Sheet, 2013).

4. Challenging in Agricultural Products

4.1 Irrigated Crops

Information on irrigated crops is scarce and incomplete. In many countries, no distinction is made between areas of irrigated and rained crops. Rice about 45 percent of all irrigated crop areas in the region and 59 percent of the rice is irrigated. However, its regional distribution shows major trends: in the countries of the Far East, Southeast Asia and the Islands, rice represents systematically more than 90 percent of irrigated crops, as is also the case for Bhutan, Nepal and Sri Lanka. In these countries, the remaining 10 percent consists of some dry season cereals, vegetables or industrial crops. Irrigation has played an important role in rice production in the second part of the twentieth century, and by the end of the 1980s many countries of the region had achieved self-sufficiency in rice.

By contrast, India, China and Korea have a much more balanced distribution of irrigated crops with rice representing only about one-third to one half of the total irrigated crop area. This reflects the cold or arid context of large parts of these countries. In India, the percentage of land under irrigated wheat is slightly higher than that under irrigated rice (31 percent against 30 percent), the rest being shared between a large variety of crops. Data for irrigated crops in China were not available but it can be estimated that it is shared evenly between rice, wheat and other crops; rice being the single most important irrigated crop. However, in India only 47 percent of the total harvested area for paddy rice is irrigated, while more that 92 percent of the harvested paddy rice in China is irrigated.

Table 5: Harvested Area of Paddy Rice

Country	Year	Harvested area of paddy in hectares			Irrigated paddy rice in % of total paddy
		Irrigated	Rainfed	Total	
Bhutan	1990	27 400	0	27 400	100
Japan	1994	2 200 000	12 000	2 212 000	99
Viet Nam	1997	6 820 700	200 000	7 020 700	97
China	1995	28 465 000	2 642 000	31 107 000	92
Korea, Rep.	1996	888 795	160 192	1 048 987	85
Brunei	1997	375	75	450	83
Malaysia	1994	433 553	265 071	698 624	62
India	1993	19 633 000	22 380 500	42 013 500	47
Philippines	1992	1 442 678	1 794 322	3 237 000	45
Bangladesh	1994	2 683 554	7 235 746	9 919 300	27
Myanmar	1995	1 591 687	4 441 013	6 032 700	26
Lao PDR	1994	160 272	450 688	610 960	26
Cambodia	1993	313 000	1 510 625	1 823 625	17
Sri Lanka	1994	661 700	5 081 175	5 742 875	12
Subtotal		65 321 714	46 173 407	111 495 121	59

4.2 Rate of Use of Irrigated Land

More or less reliable and complete information on irrigated cropping pattern is available for ten countries. Table 4 compares the total area of irrigated crops with the area equipped for irrigation. Cropping intensity varies from 72 percent in Bhutan, to 132 percent in India and Malaysia with an average of 127 percent. Care should be taken, however, when comparing figures for different countries. In Bhutan, for instance, irrigation figures refer only to summer crops. In Bangladesh (84 percent), irrigation is considered only for dry season cropping. The average irrigated cropping intensity for these ten countries is 127 percent (Irrigation in Asia , 1999).

Table 6: Intensification of Irrigation land in 10 Countries

Country	Area under irrigation ha	Irrigated crops ha	Intensification %
Bangladesh	3 75 041	3 167 756	84
Bhutan	39 734	27 900	72
India	50 101 000	66 144 000	132
Sri Lanka	570 000	666 700	120
Korea, Rep.	[illegible]	[illegible]	[illegible]

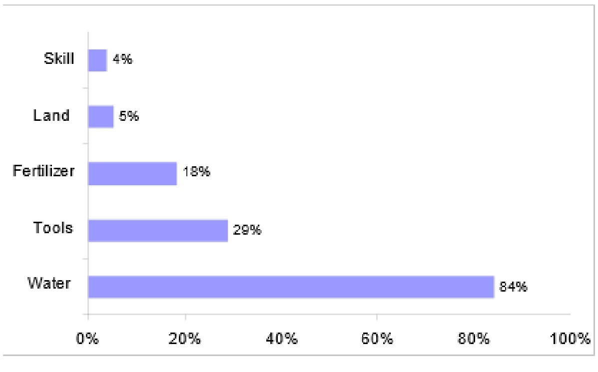
4.3 Constrain in Production

Low and volatile yield can be attributed to many constraints on the supply side. Problems on the demand side and market mechanism also affect production. On the supply side, crop cultivation is hampered by a lack of capital, a poor irrigation network, lack of agriculture extension service etc. According to an EIC survey in five different districts, the most binding constraint faced by farmers is a lack of water to irrigate farmland (see Figure I). As many as 84 percent of farmers said they face problems due to a lack of water. Lack of tools came next with 29 percent followed by a lack of fertilizers and pesticides with 18 percent. Lack of capital is also a serious constraint to production as it is the main reason after a lack of tools and inputs. Lack of skill and cultivated land are also production constraints reported by farmers.

Production constraints have brought about several negative effects for Cambodian farmers such as low yield, volatile yield, and strong seasonality. While low yield means fewer crops for sale and low income, volatile yield and seasonality mean inability to provide supply consistency. Lack of supply consistency leads to poor export performances as foreign importers do not tolerate inconsistency (Irrigation in Asia , 1999).

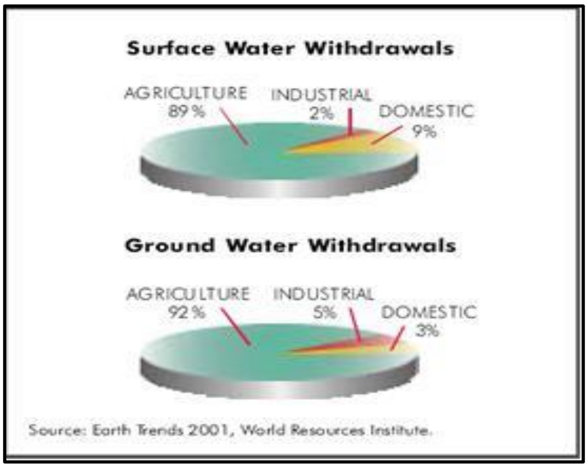
In 2006 between the domestic, agricultural, and industrial sectors, India used approximately 829 billion cubic meters of water every year, which is approximately the size of Lake Erie. By 2050 demand is expected to double and consequently exceed the 1.4 trillion cubic meters of supply.

Figure 2: Constrain in production



Source: *EIC Survey with farmers (September-November 2005)*

Figure 3 Water demand by sector



In India, despite the recent rapid growth in the services and industrial production, agriculture is still an integral part of India's economy and society. Between 1947 and 1967 India underwent the Green Revolution, which concentrated on expanding farm yields by double-cropping existing farmland and using seeds with improved genetics. The result was a huge increase in agricultural production, making India one of the world's biggest exporters of grain. The availability of canal water led farmers to adopt highly profitable, but extremely water intensive crops, such as sugar cane. In addition, India achieved its goal of obtaining food security. The rural economy sustains two-thirds of India's 1.1 billion citizens. Unfortunately, this huge surge in agriculture, required significant water resources for irrigation and accelerated the onset of present water shortages. India's agricultural sector currently uses about 90% of total water resources. Irrigated agriculture has been fundamental to economic development, but unfortunately caused groundwater depletion. Due to water pollution in rivers, India draws 80% of its irrigation water from groundwater. As water scarcity becomes a bigger and bigger problem, rural and farming areas will most likely be hit the hardest. Thus far, food security has been one of the highest priorities for politicians, and the large farming lobby has grown accustomed to cheap electricity, which allows extremely fast pumping of groundwater, which is something they are unwilling to give up for the sake of water conservation. If India wants to maintain its level of food security, farmers will have to switch to less water intensive crops. Otherwise India will end up being a net importer of food, which would have massive ramifications for the global price of grain (Brooks, 2007).

4.4 Hazards of Irrigation

Some notable hazards occur along with the benefits associated with irrigation. One is the economic risk from high irrigation costs, second is the spreading of water-related diseases. A third hazard is productivity loss caused by increased erosion and by excess salts accumulating from improper use of water. Some such soils can be reclaimed, as discussed later in this chapter, but the effort is not always economical. A fourth hazard is the risk of causing water pollution, both by sediment and associated chemicals in runoff water and by chemicals leached downward into the ground water.

Irrigation expenses arise from obvious factors such as the costs of buying water or drilling a well, purchasing additional equipment, and paying for the increased labor required to apply water to the land. Several other inputs, such as fertilizer, usually need to be increased to allow the crops to yield according to their new potentials. Oomen et al. (1990) indicate that 60% of all fertilizer used is applied to irrigated land. Another expense is caused by the constant struggle to maintain the water distribution system and to keep it free of pests such as burrowing animals and weeds. Rodent holes can cause canal banks to fail suddenly with disastrous results. Weeds growing in a canal disrupt the system by slowing the flow of water. Even weeds growing on a canal bank are a problem because their seed can be carried by the water and distributed through the fields watered from the canal. Farmers in Idaho found that one of the best solutions is to graze sheep on the canal banks; the sheep controlled both the weeds and the rodents because the rodents depended on the vegetation for cover.

Several water-related diseases that can be spread by irrigation include malaria, bilharzia, African sleeping sickness, liver fluke infections, and several others. Malaria can be controlled by varying the water level in reservoirs by about 1 fit (0.3 m) every 7 to 10 days so that fish in the reservoir can eat the mosquito larvae. Bilharzia (also called schistosomiasis) is caused by a small worm that is parasitic in human blood and needs snails as an intermediate host. The snails breed in any vegetation that grows in the water around the edge of a reservoir and can be controlled by eliminating such vegetation. African sleeping sickness (trypanosomiasis) is transmitted by the tsetse fly and is best avoided by controlling the flies.

Salt accumulations and increases in alkalinity are common in irrigated soils. Poor quality irrigation water can bring in much larger quantities of various salts than the plants growing on the soil can possibly incorporate into their tissues. Any remaining salt must either accumulate in the soil or leach into the ground water. If the ground water becomes saline, either from downward leaching salts or from salts moving laterally from higher lying soils, it can serve as a source of salts in soils with a high water table. Generally, the most saline soil will be found at relatively low elevations, for example at the lower end of a field with surface irrigation. Erosion hazards often increase with irrigation. Because surface irrigation often cuts rills, the cumulative effects of many such irrigations can be ruinous. Deposition of sediment can also be so damaging that continued irrigation becomes impractical. A well-designed program of soil and water conservation may reduce erosion to tolerable rates, but the losses usually still exceed the natural rate.

Eroded soil may carry more plant nutrients and chemical pesticides from an irrigated field than from one where rained crops are grown, both because the chemicals are likely to be applied at a higher rate and because there is likely to be more runoff and erosion from the irrigated field, especially where surface irrigation is practiced. There is also likely to be more leaching and more movement of chemicals downward to the water table. For example, Butters et al. (2000) found even more leaching of atrazine than was anticipated on the basis of the amount of irrigation water applied, possibly because of rapid water flow through soil cracks or some kind of interaction with mobile soil components.

The hazards associated with irrigation have led some observers to suggest that all irrigation systems are temporary. Some irrigation systems have never produced a marketable crop, most often because of sodic soils. Others have failed after some decades of use, most commonly because of erosion and of some means that all will sedimentation problems. Even so, some irrigation systems have endured, and it is unfair to suggest that the failure (Troech, *et al*, 2004).

4.5 Distributing Water

Canals and ditches are used to distribute water for surface and subsurface irrigation; pipelines are needed for sprinkler and trickle irrigation. Canal systems are operated by irrigation districts, companies, or cooperatives that sell water to individual farmers. Sometimes a government agency such as the U.S. Bureau of Reclamation builds the reservoirs, diversions, canals, and main ditches to deliver the water to users. Canals flow on a flatter gradient than the rivers from which they were diverted. Thus, they gradually reach a position on the side of the valley that is higher than the river. They may have to cross permeable alluvial fans, go around or through hills, and cross the valleys of tributary streams. Canals need clay or concrete linings to prevent large water losses on the alluvial fans, not only to conserve water but also to prevent them from producing seepage spots below the canal. Upland drainage and reduced grazing are needed to stabilize some hillsides where landslides and hillside sediment may obstruct the canal. Often the canal must cross tributary streams in a flume, or through a large pipeline. Valleys are expensive to cross, even if the streams are dry during the irrigation season. Water from a canal is often subdivided three or four times on its way to the fields.

A main ditch or lateral leaves the canal and flows down the divide between two tributary streams. Smaller ditches that serve a few farms branch from the lateral. Even after the water reaches the individual users, it may be divided into still more parts to irrigate individual fields and parts of fields (Troech *et al*, 2004).

5. Rain Water Harvesting technique to deal with climate change

5.1 Need for rainwater harvesting

Due to pollution of both groundwater and surface waters, and the overall increased demand for water resources due to population growth, many communities all over the world are approaching the limits of their traditional water resources. Therefore they have to turn to alternative or 'new' resources like rainwater harvesting (RWH). Rainwater harvesting has regained importance as a valuable alternative or supplementary water resource. Utilisation of rainwater is now an option along with more 'conventional' water supply technologies, particularly in rural areas, but increasingly in urban areas as well. RWH has proven to be of great value for arid and semi-arid countries or regions, small coral and volcanic islands, and remote and scattered human settlements.

Rainwater harvesting has been used for ages and examples can be found in all the great civilisations throughout history. The technology can be very simple or complex depending on the specific local circumstances. Traditionally, in Uganda and in Sri Lanka rainwater is collected from trees, using banana leaves or stems as gutters; up to 200 litres may be collected from a large tree in a single rain storm. With the increasing availability of corrugated iron roofing in many developing countries, people often place a small container under their eaves to collect rainwater. One 20-litre container of clean water captured from the roof can save a walk of many kilometres to the nearest clean water source. Besides small containers, larger sub-surface and surface tanks are used for collecting larger amounts of rainwater.

Many individuals and groups have taken the initiative and developed a wide variety of different RWH systems throughout the world.

5.1.Reason for rainwater harvesting

The reasons for collecting and using rainwater for domestic use are plentiful and varied:

1. *Increasing water needs/demand:* The increased need for water results in lower groundwater tables and depleted reservoirs. Many piped water supply systems fail. The use of rainwater is a useful alternative.

2. *Variations in water availability:* The availability of water from sources such as lakes, rivers and shallow groundwater can fluctuate strongly. Collecting and storing rainwater can provide water for domestic use in periods of water shortage. Rainwater may also provide a solution when the water quality is low or varies during the rainy season in rivers and other surface water resources (for example in Bangladesh).
3. *Advantage of collection and storage near the place of use:* Traditional sources are located at some distance from the community. Collecting and storing water close to households improves the accessibility and convenience of water supplies and has a positive impact on health. It can also strengthen a sense of ownership.
4. *Quality of water supplies:* Water supplies can become polluted either through industrial or human wastes or by intrusion of minerals such as arsenic, salt (coastal area) or fluoride. Rainwater is generally of good quality.

Briefly, the rainwater harvesting for a host of benefits accrue to the farmer and larger community from investing in decentralized rainwater harvesting structure; "***Decentralized***" means the structures are built on a farmer's own land. This gives farmers complete control over the water and leads to more efficient use, including:

- For small farmers:
  - Reduced cost of irrigation
  - Increase in irrigated area
  - Increase in agricultural production
  - Increased farm income
  - Options to extend into livestock and fisheries
- For local environment and ecology
  - Groundwater recharge
  - Return of wildlife
  - Reduction in diesel and electricity consumption
- For society/economy
  - Increase in agricultural p1roduction
  - Greater food security

5.2.Advantages and disadvantages

Rainwater harvesting provides an independent water supply during regional water restrictions and in developed countries is often used to supplement the main supply. It provides water when there is a drought, prevents flooding of low-lying areas, replenishes the ground water level, and enables dug wells and bore wells to yield in a sustained manner. It also helps in the availability of clean water by reducing the salinity and the presence of iron salts. Makes use of a natural resource and reduces flooding, storm water, erosion, and contamination of surface water with pesticides, sediment, metals, and fertilizers.

- Excellent source of water for landscape irrigation, with no chemicals such as fluoride and chlorine, and there is no dissolved salts and minerals from the soil.
- Home systems can be relatively simple to install and operate and it may reduce your water bill.
- Promotes both water and energy conservation.
- No filtration system required for landscape irrigation.

However, RWH has some disadvantages. The main disadvantage of RWH is that one can never be sure how much rain will fall. Other disadvantages, like the relatively high investment costs and the importance of maintenance, can largely be overcome through proper design, ownership and by using as much locally available material as possible to ensure sustainability (and cost recovery). The involvement of the local private sector and local authorities can facilitate up scaling of RWH.

When considering the possibility of using rainwater catchment systems for domestic supply, it is important to consider both the advantages and disadvantages and to compare these with other available options. RWH is a popular household option as the water source is close by, convenient and requires a minimum of energy to collect. An advantage for household systems is that users themselves maintain and control their systems without the need to rely on other members of the community. Since almost all roofing material is acceptable for collecting water for household purposes, worldwide many RWH systems have been implemented successfully.

Table 7: Advantages and disadvantages of rainwater harvesting

Advantages	Disadvantages
Simple construction: Construction of RWH systems is simple and local people can easily be trained to build these themselves. This reduces costs and encourages more participation, ownership and sustainability at community level.	*High investment costs*: The cost of rainwater catchment systems is almost fully incurred during initial construction. Costs can be reduced by simple construction and the use of local materials.
Good Maintenance: Operation and maintenance of a household catchment system are controlled solely by the tank owner's family. As such, this is a good alternative to poor maintenance and monitoring of a centralised piped water supply.	*Usage and maintenance*: Proper operation and regular maintenance is a very important factor that is often neglected. Regular inspection, cleaning, and occasional repairs are essential for the success of a system.
Relatively good water quality: Rainwater is better than other available or traditional sources (groundwater may be unusable due to fluoride, salinity or arsenic).	*Water quality is vulnerable*: Rainwater quality may be affected by air pollution, animal or bird droppings, insects, dirt and organic matter.
Low environmental impact: Rainwater is a renewable resource and no damage is done to the environment.	*Supply is sensitive to droughts*: Occurrence of long dry spells and droughts can cause water supply problems.
Convenience at household level: It provides water at the point of consumption.	*Limited supply*: The supply is limited by the amount of rainfall and the size of the catchment area and storage reservoir.
Not affected by local geology or topography: Rainwater collection always provides an alternative wherever rain falls.	
Flexibility and adaptability of systems: to suit local circumstances and budgets, including the increased availability of low-cost tanks (e.g. made of Ferro cement, plastics or stone/bricks).	

5.2 Basic principles of rainwater harvesting

5.2.1 Definition

Water harvesting in its broadest sense can be defined as the collection of run-off rainwater for domestic water supply, agriculture and environmental management. Water harvesting systems, which harvest runoff from roofs or ground surfaces fall under the term rainwater harvesting.

5.2.2 Catchment surface

The catchment of a water harvesting system is the surface that receives rainfall directly and drains the water to the system. Surface water is, however, in most cases not suitable for drinking (Janette & Tim , Rainwater harvesting for domestic use, 2006) purposes since the water quality is not good enough. Any roofing material is acceptable for collecting water. However, water to be used for drinking should not be collected from thatched roofs or roofs covered with asphalt. Also lead should not be used in these systems. Galvanised, corrugated iron sheets, corrugated plastic and tiles make good roof catchment surfaces. Flat cement or felt-covered roof can also be used provided they are clean. Undamaged asbestos cement sheets do not have a negative effect on the water quality. Small damages may, however, cause health problems!

5.2.3 Groundwater Resources

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well. The study of water flow in aquifers and the characterization of aquifers is called hydrogeology. Related terms include aquitard, which is a bed of low permeability along an aquifer, and aquiclude (or aquifuge), which is a solid, impermeable area underlying or overlying an aquifer. If the impermeable area overlies the aquifer pressure could cause it to become a confined aquifer.

5.2.4 Delivery system

The delivery system from the rooftop catchment usually consists of gutters hanging from the sides of the roof sloping towards a downpipe and tank. This delivery system or guttering is used to transport the rainwater from the roof to the storage reservoir. For the effective operation of a rainwater harvesting system, a well-designed and carefully constructed gutter system is crucial because the guttering is often the weakest link in a rainwater harvesting system. As much as 90% or more of the rainwater collected on the roof will be drained to the storage tank if the gutter and downpipe system is properly fitted and maintained. Common material for gutters and downpipes are metal and PVC. With high intensity rains in the tropics, rainwater may shoot over the (conventional) gutter, resulting in rainwater loss and low harvesting production; splash guards can prevent this spillage.

5.2.4.1 First flush diverters

A roof can be a natural collection surface for dust, leaves, blooms, twigs, insect bodies, animal fences, pesticides, and other airborne residues. The first flush diverter routes the first flow of water from the catchment surface away from the storage tank. The flushed water can be routed to a planted area. While leaf screens remove the larger debris, such as leaves, twigs, and blooms that fall on the roof, the first-flush diverter gives the system a chance to rid itself of the smaller contaminants, such as dust, pollen, and bird and rodent fences.

5.2.4.2 Storage reservoirs

The water storage tank usually represents the biggest capital investment element of a domestic RWH system. It therefore usually requires the most careful design – to provide optimal storage capacity and structural strength while keeping the costs as low as possible. Common vessels used for very small-scale water storage in developing countries include plastic bowls and buckets, jerry cans, clay or ceramic jars, old oil drums or empty food containers.

For storing larger quantities of water the system will usually require a tank above or below the ground. Tanks can vary in size from a cubic metre (1,000 litres) up to hundreds of cubic metres for large reservoirs. In general the size varies from 10 up to a maximum of 30 cubic metres for a domestic system at household level and 50 to 100 cubic metres for a system at community or school level, of course very much dependent on the local rain pattern throughout the year. Round shaped tanks are generally stronger than square-shaped tanks. Furthermore, round-shaped tanks require less material compared to the water storage capacity of square tanks.

5.3. Design a Rain Water Harvesting System

5.3.1. Step 1: Determine the rainwater storage tank capacity

a). Estimating domestic water demand

The first step in designing a rainwater harvesting system is to consider the annual household water demand. To estimate water demand the following equation can be used:

Demand = Water Use × Household Members × 365 days

For example, the water demand of one household is 31,025 litres per year when the average water use per person is 17 litres per day and the household has 5 family members: Demand = 17 litres × 5 members × 365 days = 31,025 litres per year

However, in reality it may not be so easy. Children and adults use different amounts of water and seasonal water use varies, with more water being used in the hottest or driest seasons. The number of household members staying at home may also vary at different times of the year. By estimating the average daily water use these variables should be taken into account. Domestic water demand includes all water used in and around the home for the following essential purposes: drinking, food preparation and cooking, personal hygiene, toilet flushing (if used), washing clothes and cleaning, washing pots and pans, small vegetable gardens, and other economic and productive uses (the latter only when sufficient rainwater is available).

b). Rainfall data

The next step is to consider the total amount of available water, which is a product of the total annual rainfall and the roof or collection surface area. These determine the potential value for rainwater harvesting. Usually there is a loss caused mostly by evaporation (sunshine), leakage (roof surface), overflow (rainwater that splashes over the gutters) and transportation (guttering and pipes). The local climatic conditions are the starting point for any design. Climatic conditions vary widely within countries and regions. The rainfall pattern or monthly distribution, as well as the total annual rainfall, often determine the feasibility of constructing a RWH system.

In a climate with regular rainfall throughout the year the storage requirement is low and the system cost will be low too. It is thus very important to have insight into local (site-specific) rainfall data. The more reliable and specific the rainfall data is, the better the design can be. In mountainous locations and locations where annual precipitation is less than 500 mm per year (Janette & Tim , 2006), rainfall is very variable. Data from a rain gauging station 20 km away may be misleading when applied to your system location. Rainfall data can be obtained from a variety of sources. The primary source should be the national meteorological organisation in the country. In some countries, however, rainfall statistics are limited due to lack of resources. Local water departments or organisations, local hospitals, NGOs or schools may be possible sources of rainfall information. To be clear how much you collect rainwater per year should be formula by roof top area multiply average of rainfall (m) and then multiply by collection efficiency.

Total quantity of rainwater collection (cu.m.)= Roof top area (sq.m.) x Average of Rainfall (m) x Collection efficiency

The amount of available rainwater depends on the amount of rainfall, the area of the catchment, and its run-off coefficient. For a roof or sloping catchment it is the horizontal plan area which should be measured. The run-off coefficient (RC) takes into account any losses due to evaporation, leakage, overflow and transportation. To formula the potential of rainwater harvesting should be consider as follow:

Water harvesting potential = Rainfall (mm) x Collection efficiency

5.3.2 Step 2: Determine the catchment area

Four main groups of water harvesting techniques can generally be distinguished: micro and macro-catchments, floodwater harvesting and storage reservoirs. Typically, micro-catchment techniques involve the delineation of natural depression, the construction of contour and stone bunds, system for inter-row rainwater harvesting, terracing, construction of semi-circular (half-moon) and triangular (V-shaped) bunds, eyebow tarraces, vallerani-type micro-catchment, pits, meskats, and negarims.

Macro-catchment include large semi-circular and trapezoidal bund, and hillside conduits. Floodwater can be harvested within the stream bed or diverted to the cropping fields. Storage media include underground storage reservoirs such as soil and sediment, and cistern and surface media like tanks, jars, ponds and reservoirs. An excellent overview of all these techniques can be found in FAO (2003).

The catchment of water-collection area can be a roof top, a small land surface and a slope of a larger catchment area feeding seasonal water courses. (Donald, Wim, & Wouter, 2008).

5.3.2.1 Micro-catchment

Micro-catchments are mainly used for growing trees or bushes. This technique is appropriate for small-scale tree planting in any area with a moisture deficit. It also conserves the soil. In Israel micro-catchments are popular for growing fruit trees, the local name is 'Negarim'. Because this technique has proven to be successful and is easy to carry out, it is advisable to try it out before starting other more difficult techniques.

Micro-catchment water harvesting systems (MicroWH) are designed to trap and collect runoff from a relatively small catchment area, usually (10 – 500 m^2) within the farm boundary. The runoff water is guided into an application area where it accumulates in holes, pits, basins and bunds. It infiltrates into the soil, and is used to grow plants. The collected water is stored in the root zone and supplies crops such as sorghum, millet, maize, shrubs, trees or fodder crops. The ratio between the catchment (collection) areas to the cultivated (application) area can vary between 2:1 and 10:1. The size of the catchment can be easily controlled by the farmer, which makes the system easy to adapt and replicate. MicroWH are small systems replicated many times with identical designs. Catchment and application areas are alternating within the same field, thus rainwater is concentrated on a confined surface where plants are grown. In comparison, MacroWH are much larger systems with one catchment outside the cultivated area.

a). Resilience to climate variability

Water harvesting in micro-catchments reduces risks of production failure due to water shortage associated with rainfall variability and dry spells. It accumulates and concentrates water and enables crop growth (including establishment of trees) in areas where rainfall is normally not sufficient, or unreliable. Although runoff farming methods can increase the water availability, climatic risks still exist and in years with extremely low rainfall, it cannot compensate for overall water shortages.

b). Main benefits

- Increased water availability, reduced risk of production failure, enhanced crop, fodder and tree production and improved water use efficiency.
- Simple to design and control, and cheap to install (and to adapt) by individual farmers, therefore easily replicable.
- Higher runoff collection efficiency than medium or large-scale water harvesting systems; negligible conveyance losses.
- Erosion control and trapping of nutrient-rich sediments in runoff.
- The area to be prepared for planting as well as fertilizer inputs are reduced compared to conventional preparation of the entire field, while overall production is improved and the risk of failure reduced.

c). Main disadvantages

- Catchment uses potentially arable land (with the exception of steep slopes).
- Catchment area has to be maintained, i.e. kept free of vegetation. However, crusts often develop on bare surfaces of the catchment and therefore naturally reduce weed growth.
- As in all water harvesting systems, systems can be damaged during exceptionally heavy rainstorms.

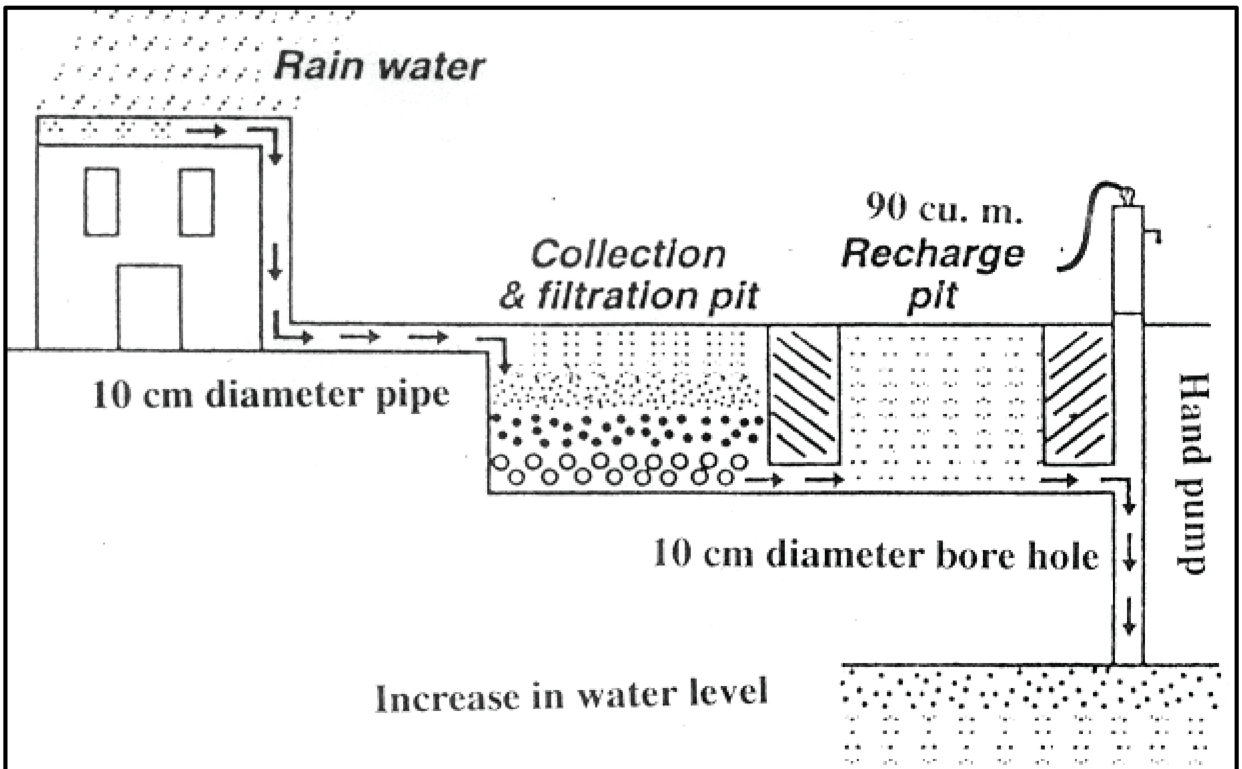
- If maintenance is inadequate, soil erosion can occur and initial investment will belost.

d). Rooftop Systems

The water supply is under tremendous stress due to growing population's demand of water for various uses. The over exploitation of ground water has exceeded the recharge. The water table is declining at an alarming rate. This is an old runoff water harvesting technique widely adopted in acid highland which occupied runoff watercourse. It has been found the most appropriate method for augmenting groundwater level artificially in the area where recharge is considerably reduced due to increased urban activities and not much of land is available for implementing any other artificial recharge measures (Sharma, 2007).

Why rooftop rainwater harvesting? - The population increasing is facing a serious threat to the management of water resources as the gap between demand and supply is continuously widening. The declining recharge rate coupled with over draft situation of groundwater has resulted in the fall of water level due to depletion of groundwater storage. The residents are, therefore, facing an acute shortage of water for various purposes especially during non-monsoon days when the water level touches all-time low. In addition, abundant building structures and group housing societies like in any other mega city are also available in the city. Combination of a good average rain fall and required roof tops makes the situation ideal for conservation of roof-top rain water area during monsoon timers to augment groundwater storage by artificial recharge which otherwise is lost to surface runoff. This artificial recharge mechanism which is a synonymous phenomenon of replenishment of groundwater resources is conductive to transforming the surface water into existing aquifer system within prevailing hydrogeological environment (Curtis, 1998).

Figure 4: Schematic representation of underground trench layout



5.3.2.2 Macro-catchment

Macro-catchment water harvesting (MacroWH) systems usually consist of four components: the catchment area, the runoff conveyance system, the storage system and the application area. In the catchment area, rainwater runoff is collected from compacted surfaces, including hillsides, roads, rocky areas, open rangelands, cultivated and uncultivated land and natural slopes. Most MacroWH practices have a catchment area of less than 2 ha, in some cases however runoff is collected from catchments as large as 200 ha. The runoff is conveyed through overland, rill, gully or channel flow and either diverted onto cultivated fields (where water is stored in the soil) or into specifically designed storage facilities. There were concentrated runoff is directly diverted to fields, the application area is identical with the storage area, as plants can directly use the accumulated soil water. The application or cropping area is either terraced or located in flat terrain. The ratio of the catchment to the application area (usually cultivated) varies between 10:1 and 100:1. In the second case, a great variety of designed storage systems keep the water till it is used either adjacent to the storage facilities or further away (involving a conveyance system) (Rima & Hanspete, 2013).

a). Resilience to climate variability

Macro-catchment systems are resilient to climate change as long as there is at least some precipitation and runoff. Several consecutive drought years always pose a problem, depending on the size of the storage system: they may lead to reservoirs failing to fill. During short dry spells Macro-catchment systems provide an adaptation option for land users, as they can use the stored water for supplementary irrigation (Rima & Hanspete, 2013).

b). Main benefits

- Improved crop yields.
- Improved year-round access to water for domestic and livestock consumption, as well as for supplementary irrigation.
- Reduced risk of crop failure by bridging prolonged dry periods and as such contribute to food security and climate change adaptation.
- Reduced damage from soil erosion and flooding by storing excess runoff water. Main disadvantages
- Open and shallow rainwater ponds and dams may dry out after the rainy seasons, as the water is lost via seepage (except for rock catchment and sand dams) and evaporation.
- Health risks: open storage structures can be contaminated by animals and can provide a breeding ground for disease-carrying insects. Sand dams are often contaminated as they are seldom protected from animals.

- **Floodwater systems**

It is on old technique which diverts the total or a portion of the floodwater carried by wadis-dry riverbeds that only contain water during and immediately after heavy rains-to the neighboring cultivated fields, in the form of natural irrigation. It has three components including a diversion dam, a distribution network and the cropping fields. The diversion dam is generally made of earth acting as a fuse by breaking down in case of very intense floods. Recently, gabions and reinforced concrete are becoming most popular. The distribution network is made of open trapezoidal canals (primary, secondary, tertiary,…) with gentle slopes except in partition points to avoid silting up. The cropping fields are generally flat with a rectangular shape and delineated by earthen embankments to retain up to 1m of water.

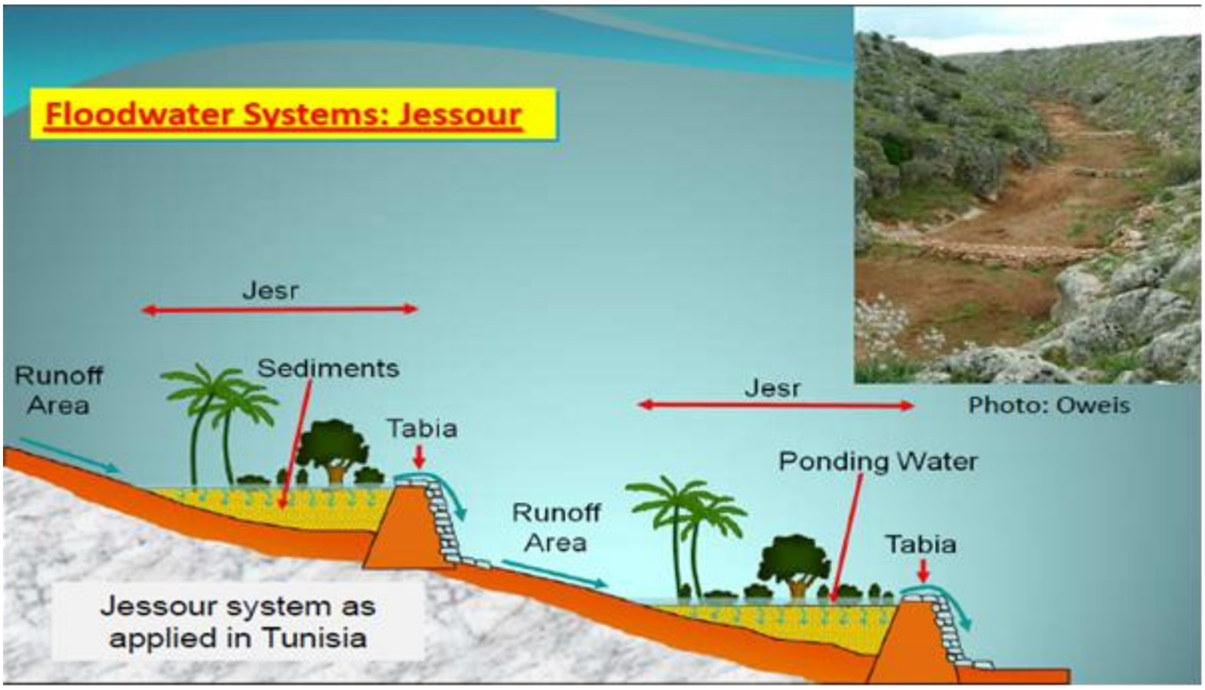


Figure 7: Floodwater System

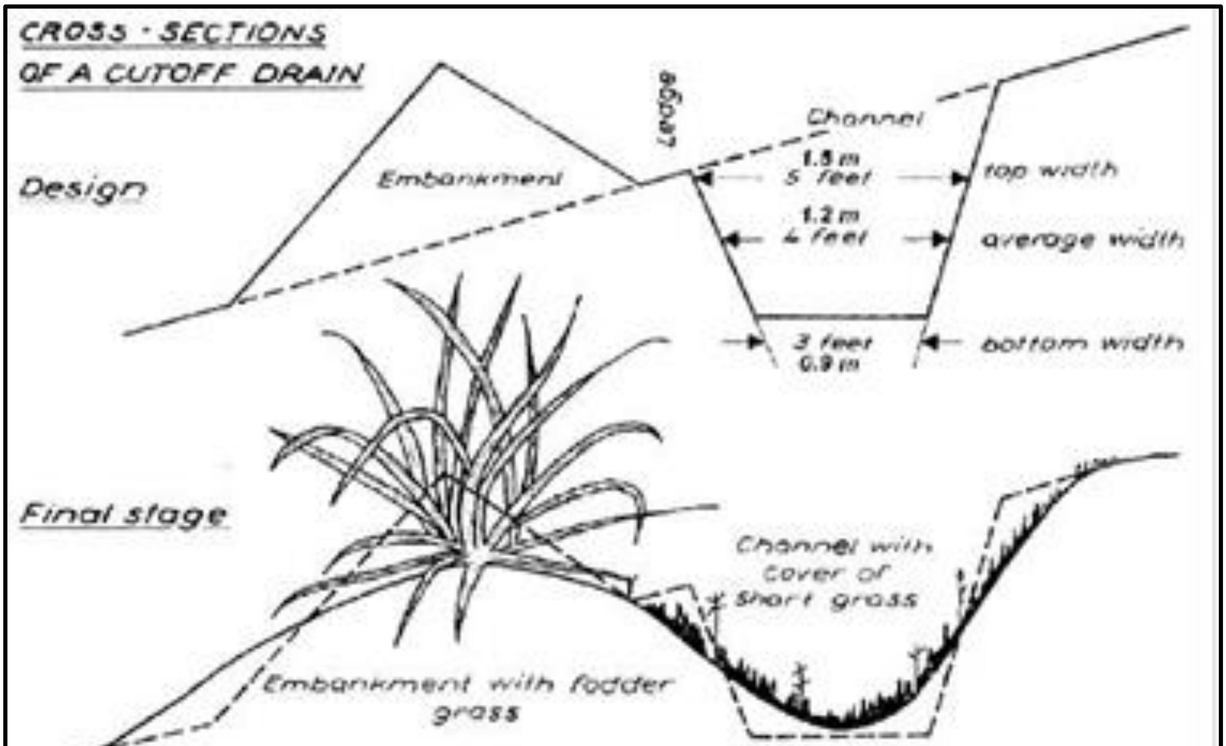
- **Hillside runoff/conduit**

Small conduits guide and concentrate runoff water on slopes (>10%) and deliver it to flat fields at the foot of the slope (0% – 10%). Fields are levelled and surrounded by impounding walls / bunds with a spillway to drain excess water to downstream fields. Once all fields in a series are filled, the water rejoins the natural watercourse. The catchment to application area (C:A) is commonly 10:1 – 100:1, it can reach 175:1. Through this system, rainfall runoff from bare or sparsely vegetated hilly or mountainous areas can be collected. The system is found in many semi-arid hill or mountainous regions with annual rainfall of 100 – 600 mm. It can be applied for many crops and fruit trees especially those that tolerate water-logging. In Pakistan this system is called sylaba / sailaba, in Somalia cage and in Turkmenistan takyr cultivation.

- **Cut-off drains**

A cut-off drain safely discharges runoff water to a waterway. From there water flows either into the natural drainage system or is harvested in storage facilities for further use. Cut-off drains are dug across a slope to intercept surface runoff and carry it safely to an outlet such as a canal or stream. Soil dug is heaped to a ridge below the trench, which acts as embankment protection in case of overtopping. It is suitable for all land uses; but often constructed between different slopes or land uses. Cut-off drains are mainly used to protect cultivated land, compounds and roads from uncontrolled runoff, and to divert water from gully heads. In dry areas they can act as infiltration and water retention ditches.

Figure 9: Cut-off drain



- **Ponds for groundwater recharge**

These man-made depressions fill with runoff water and eventually feed underground freshwater “lenses” floating on top of the saline aquifer (e.g. tajamares in Uruguay and Paraguay, chirle in Turkmenistan). Water pumps are used to pump the water back up to the surface. The water is used for livestock consumption and domestic use after filtration and/or chlorination but also serves to artificially recharge groundwater aquifers. Artificial recharge through infiltration ponds can be applied almost anywhere, provided that there is a supply of clean fresh water available at least part of the year, the bottom of the pond is permeable, and the aquifer to be recharged is at or near the surface.

Figure 10: Pond for Groundwater recharge

- **Household Consumption**

Where water is very scarce, people may use as little as 3 to 4 litres per person per day for drinking only, while about 15-25 litres per person will be sufficient for drinking, cooking and personal hygiene. These quantities vary per country, community, and household, and also vary over time as consumption rates may change in different seasons.

Management of water at household and community level remains important. Particular- ly, during the dry season or when water levels are low, the allocation or use of the remaining water should be restricted. (Janette & Tim, Rainwater harvesting for domestic use, 2006)

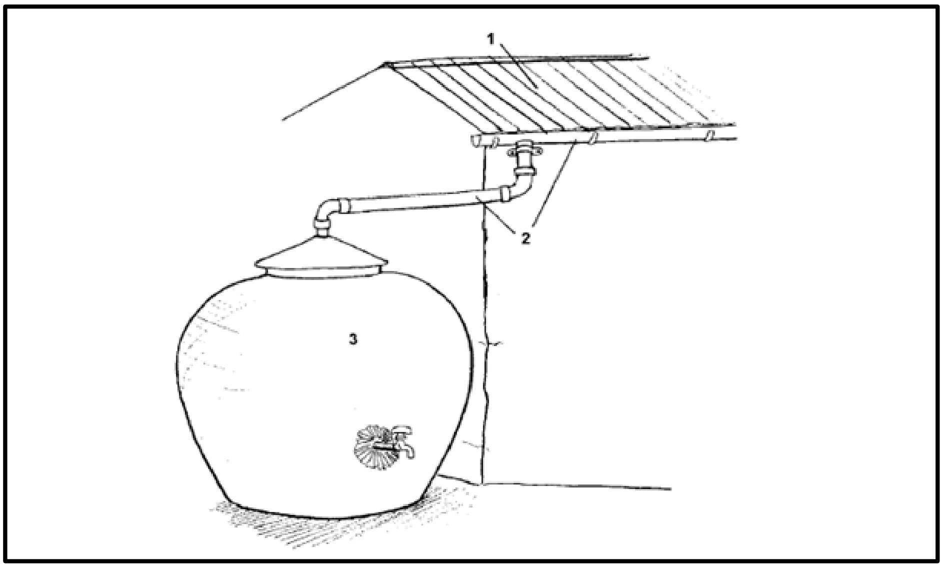


Figure 11: Three basic components of a rainwater harvesting system (1) Catchment, (2) Deliver system, (3) Storage reservoir

5.3.3 Step 3: Designing your delivery systems

The collected water from a roof needs to be transported to the storage reservoir or tank through a system of gutters and pipes, the so-called delivery system or guttering. Several other types of delivery systems exist but gutters are by far the most common. Commonly used materials for gutters and downpipes are galvanised metal and plastic (PVC) pipes, which are readily available in local shops. There is a wide variety of guttering available from prefabricated plastics to simple gutters made on-site from sheet metal. In some countries bamboo, wood stems and banana leaves have been used. Gutters made from extruded plastic are durable but expensive. For the guttering, aluminium or galvanised metals are recommended because of their strength, while plastic gutters may suffice beneath small roof areas. Almost all plastics, certainly PVC, must be protected from direct sunlight. Generally, the cost of gutters is low compared to that of storage reservoirs or tanks, which tend to make up the greatest portion of the total cost of a RWH system.

Gutters are readily available in different shapes; they can be rounded, square, V-shaped, and have open or closed ends with attached downpipe connectors.

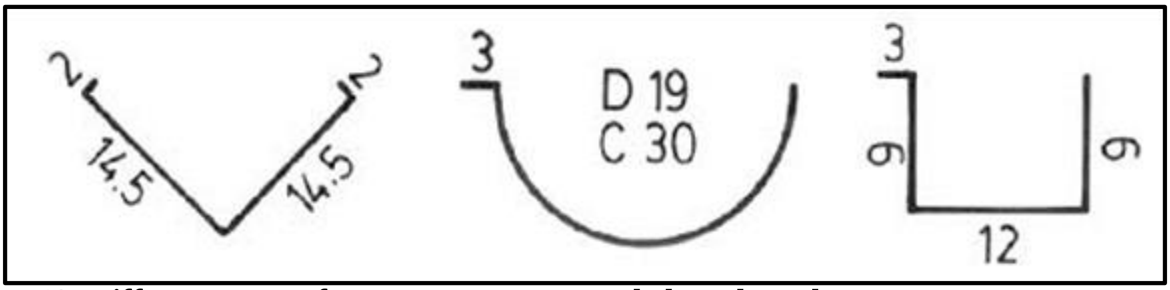


Figure 12: Different types of gutters: square, rounded, V-shaped

a). Semi-circle gutters

Plastic extrusion is the simplest way to make semi-circular gutters. Raw plastic material is melted and formed into a continuous profile. Alternatively gutters can also be produced by cutting a tube (or a bamboo pole) in half. Such gutters are not only cheap but also easy to clean.

b). V-shaped gutters

These are made by cutting and folding flat galvanized steel sheets. One of the simplest ways to construct a V-shaped gutter is to clamp the cut sheet between two lengths of straight timber and to fold the sheet along the edge of the wood. Edges are strengthened by folding the sheet by 90°, and then completing the edge with a hammer on a hard surface. But this type of gutter is easily blocked by twigs and leaves.

c). Square-sectioned gutters

Metal sheets are folded and shaped by using a piece of wood to achieve a square section. This type of gutter is prone to silting. Wooden planks and bamboo gutters: These are the cheapest form of gutters – practically free at the local level. However, they require frequent replacement. Moreover, they can be difficult to clean and runoff is often tainted.

To avoid water overshooting the gutters, gutter guards or splash guards can be installed:

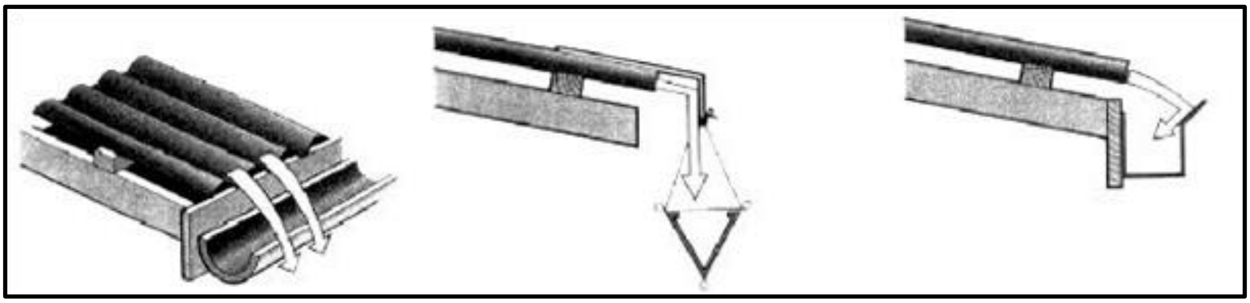


Figure 13: The way of gutters installation

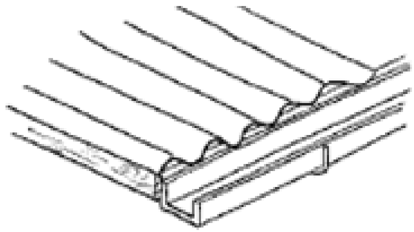


Figure 13: Square-sectioned gutter

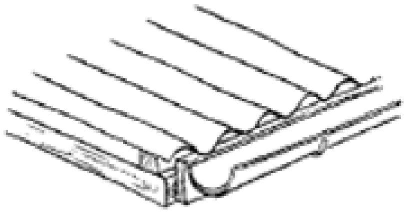


Figure 14: Semi-circle gutters

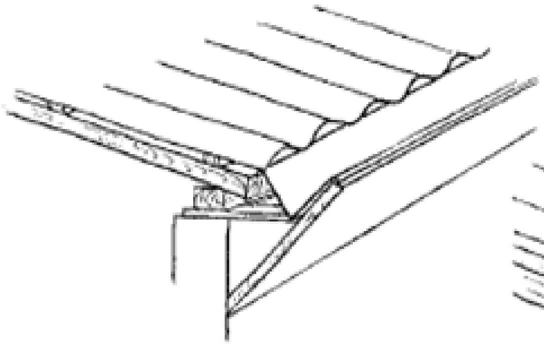


Figure 15: V-shaped gutters

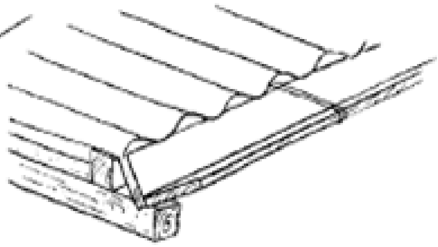


Figure 16: V-shaped gutters

Proper construction of gutters is essential to avoid water losses. Gutters must slope evenly towards the tank to ensure a slow flow. Gutters are often the weak link in a RWH system and installations can be found with gutters leaking at joints or even sloping the wrong way.

Aluminium is naturally resistant to corrosion, which makes it last indefinitely. The cost of an aluminium sheet is over 1.5 times the cost of steel of the same thickness and the material is less stiff so for a similar strength of gutter a larger thickness of material is required, resulting in gutters that are up to three times more expensive. Nevertheless, there is a growing market for aluminium sheets in developing countries so the price will almost certainly come down over time. Half pipes have been proposed as an inexpensive form of guttering and are used in many areas. The production is relatively simple, and the semi-circular shape is extremely efficient for RWH. The cost of these gutters depends on the local cost of piping, which may be more expensive than an equivalent sheet metal gutter.

5.3.4 Step 4: Sizing your storage reservoir

Storage reservoirs are usually the most expensive component in any roof catchment system and choosing the most appropriate type is important. The choice of tank will depend on the range and price of locally available commercial options and on the cost and availability of building materials. A typical 2000 square foot house will have a roof rainwater run-off of 56,000 gallons annually if located in Oregon City where annual rainfall averages 45 inches, or up to 105,000 gallons annually if located in Welches with an annual rainfall of 85 inches.

Table 8: Sizing storage reservoir

Roof Square Footage	45 inches/year Oregon City	60 inches/year Sandy	85 inches/year Welches
1500	42,000 gallons harvested	56,000 gallons harvested	79,000 gallons harvested
2000	56,000 gallons harvested	74,000 gallons harvested	105,000 gallons harvested
2500	70,000 gallons harvested	93,000 gallons harvested	132,000 gallons harvested
3000	84,000 gallons harvested	112,000 gallons harvested	159,000 gallons harvested

5.3.5 Step 5: Selection of a suitable storage reservoir design

Suitable design of storage reservoirs depend on local conditions, available materials and budget, etc. Storage reservoirs are usually the most expensive component in any roof catchment system and choosing the most appropriate type is important. The choice of tank will depend on the range and price of locally available commercial options and on the cost and availability of building materials. In the following sections, examples are given in a step-by-step approach of how these factors translate into practical situations.

Figure 17: Dead storage

5.4 Water quality aspects

Rainwater is often used for drinking and cooking and so it is vital that the highest possible standards are met. Rainwater, unfortunately, often does not meet the World Health Organization (WHO) water quality guidelines. This does not mean that the water is unsafe to drink. Gould and Nissan-Peterson (1999), in their recent book, point out that the Australian government have given the all clear for the consumption of rainwater ‘provided the rainwater is clear, has little taste or smell, and is from a well-maintained system’. It has been found that a favorable user perception of rainwater quality (not necessarily perfect water quality) makes an enormous difference to the acceptance of RWH as a water supply option.

5.4.1 Contaminants in rainwater

The water in a raindrop is one of the cleanest sources of water available. Rainwater can absorb gases such as carbon dioxide, oxygen, nitrogen dioxide, and sulfur dioxide from the atmosphere. It can also capture soot and other microscopic particulates as it falls through the sky. Nevertheless, rainwater is almost 100% pure water before it reaches the ground.

Pure water is considered the universal solvent; it can absorb or dissolve contaminants from almost anything it comes into contact with. That is why it is especially important to design and operate your system so that the rainwater picks up as few contaminants as possible before you consume it.

a). Debris

We use the term “debris” to describe any contaminant that you can see. Debris includes leaves and twigs, dust and dirt, bird and animal droppings, insects, and other visible material. Although debris obviously reduces the aesthetic quality of the water, it can also pose unseen chemical and biological health threats. For example, leaves and dust can contain unseen chemical contaminants such as herbicides and pesticides. Similarly, bird and animal droppings can contain microscopic parasites, bacteria and viruses.

b). Chemical Contaminants

Although rainwater can be contaminated by absorbing airborne chemicals, most of the chemicals present in harvested rainwater are introduced during collection, treatment, and distribution. By properly designing and operating your rainwater harvesting system, you can minimize your exposure to a variety of chemical contaminants that include organic chemicals, such as volatile and synthetic organics, and inorganic chemicals, such as minerals and metals.

c). Metals

Metals include lead, arsenic, copper, iron, and manganese. Some metals, such as lead and arsenic, can pose a long-term health threat if they are present in high enough concentrations. Other metals, such as iron and manganese, can affect the appearance and taste of the water but pose no health threat. It takes time for metal to dissolve in rainwater. Therefore, this type of contaminant is usually present only after metallic materials such as lead solder, iron and copper pipe, and brass fittings have been exposed to rainwater for several hours or longer.

5.4.2 Protecting water quality

Generally the chemical quality of rainwater will fall within the WHO guidelines and rarely presents problems. There are two main issues when looking at the quality and health aspects of DRWH:

Firstly, there is the issue of bacteriological water quality. Rainwater can become contaminated by faces entering the tank from the catchment area. It is advised that the catchment surface always be kept clean. Rainwater tanks should be designed to protect the water from contamination by leaves, dust, insects, vermin, and other industrial or agricultural pollutants. Tanks should be sited away from trees, with good fitting lids and kept in good condition. Incoming water should be filtered or screened, or allowed to settle to take out foreign matter (as described in a previous section). Water which is relatively clean on entry to the tank will usually improve in quality if allowed to sit for some time inside the tank. Bacteria entering the tank will die off rapidly if the water is relatively clean. Algae will grow inside a tank if sufficient sunlight is available for photosynthesis. Keeping a tank dark and sited in a shady spot will prevent algae growth and also keep the water cool. As mentioned in a previous section, there are a number of ways of diverting the dirty 'first flush' water away from the storage tank. The area surrounding a RWH should be kept in good sanitary condition, fenced off to prevent animals fouling the area or children playing around the tank. Any pools of water gathering around the tank should be drained and filled.

Gould points out that in a study carried out in north-east Thailand 90 per cent of in-house storage jars were contaminated whilst only 40% of the RWH jars were contaminated. This suggests secondary contamination (through poor hygiene) is a major cause of concern.

Secondly, there is a need to prevent insect vectors from breeding inside the tank. In areas where malaria is present, providing water tanks without any care for preventing insect breeding, can cause more problems than it solves. All tanks should be sealed to prevent insects from entering. Mosquito proof screens should be fitted to all openings. Some practitioners recommend the use of 1 to 2 teaspoons of household kerosene in a tank of water which provides a film to prevent mosquitoes settling on the water. There are several simple methods of treatment for water before drinking.

- Boiling water will kill any harmful bacteria which may be present
- Adding chlorine in the right quantity (35ml of sodium hypochlorite per 1000 litres of water) will disinfect the water
- Slow sand filtration will remove any harmful organisms when carried out properly
- A recently developed technique called SODIS (SOlar DISinfection) utilises plastic bottles which are filled with water and placed in the sun for one full day. The back of the bottle is painted black. More information can be found through the Resource Section at the end of this document.

5.4.3 Rainwater quality and treatment guidelines

There are currently no national water quality guidelines that pertain specifically to the use of rainwater. The Canadian guidelines for domestic reclaimed water for use in toilet and Urinal Flushing (2010) are not intended for rainwater use, but may be applied for multi-residential or commercial systems where there is the potential for direct contact. For single-family dwellings, the quality of rainwater and the need for treatment must be evaluated in the context of connected fixtures. Connected fixtures where there is minimal contact with the rainwater do not require the same quality of water as applications where users come into direct contact with the water. Treatment needs should be determined on a case by case basis by local building or health authorities, considering the recommendations of designers and preferences of end users.

a). Treatment of stored water

Treatment of stored rainwater makes sense only if it is done properly. There are several possible treatment methods, the most common being sand filters, chlorination, boiling and exposure to sunlight.

b). Sand filters

Sand filters provide a cheap and simple method to purify water. Two filter types can be used: a filter can be connected to the tank to filter ALL the water as it enters the tank. Such a filter can provide 50 liters of water per day – enough for the drinking and cooking needs of a small family. However, this filtering method is only suitable where the inflow is slow. The second filtering type is a so-called point of use filter, which unlike the first option is not located at the inflow point. Water for drinking purposes is filtered through a portable sand filter. This second type is highly recommended.

In a sand filter, additional layers of gravel and charcoal are also commonly used to further improve the filtering capacity and thus the water quality. Sand filters do require careful operation and maintenance to ensure they continue to work effectively.

c). Chlorination

Chlorination can be an effective way to purify the water. The chlorine will, however, affect the taste of the water and over-application can cause health problems. If you suspect the water in your tank is contaminated, adding calcium hypochlorite or sodium hypochlorite should treat it. The initial dose should be 7 g of calcium hypochlorite or 40 ml of sodium hypochlorite per 1000 liters of water in the tank. The water should be stirred and left to stand for 24 hours (no additional water may enter the reservoir). To maintain a safe water supply after this initial dosage, 1 g of calcium hypochlorite or 4 ml of sodium hypochlorite per 1000 liters should be added to the rainwater tank weekly and the mixture should be allowed to stand for at least two hours before use. Stabilized chlorine (chlorinated cyan rates) should not be used. Some important rules for using chlorine:

- Do not pour water onto chlorine, but always add chlorine to water.
- Avoid skin contact.
- Store chlorine in a cool, dark place, out of reach of children.

To ensure that sufficient chlorine has been added, the water is normally tested with a simple color-coded testing kit for residual chlorine. Normally a chlorine residue in the range of 0.2 – 0.5 mg/liter indicates safe drinking water.

d). Boiling

Boiling water for two or three minutes normally ensures that it is free from harmful bacteria or pathogens. However, boiling requires a lot of energy and in some areas this might be a problem due to shortage of fuel or wood. Many people do not like the flat taste of boiled water and it takes time for it to cool down before you can drink it.

e). Sunlight

Another way to kill many harmful bacteria in water is to put it into clear glass or plastic bottles and place them in direct sunlight for several hours. This method is known as Solar Water Disinfecting (SODIS). The process works in two ways: bacteria and microorganisms are killed both by exposure to direct radiation and, if heated sufficiently, by water temperatures exceeding 70°C. It is most effective when the water is fully oxygenated, so leaving some air in the bottles and shaking the bottle occasionally will speed up the process. Painting the bottles black increases absorption of radiation and increases the heat. (See www.sodis.ch for more detailed information).

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