Module 2: Impacts of Climate Change on Landscapes

Introduction

As indicated in Module 1, there is clear scientific evidence that the global climate is changing due to the accumulation of greenhouse gases in the atmosphere. In this module, we will explore further what is causing the climate to change and the impacts this has on landscapes. Further, this module explains what climate scenarios are and shares some information on climate trends for Afghanistan.

What causes the climate to change?

Gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) are called greenhouse gases (GHGs). Together with aerosols, such as water vapour and particulate matter from burning of fossil fuels, GHGs in the atmosphere keep the earth warm just like the warming inside a greenhouse.

Radiations from the sun travel through the atmosphere and warm the earth's surface. Part of the incoming energy leaves the planet in the form of heat (infrared radiation). On its way out through the atmosphere, this heat is absorbed by GHGs that act as a blanket over the earth, keeping it warm. This effect is essential for keeping the earth warm enough to support life. However, human actions (anthropogenic factors) such as increased burning of fossil fuels and industrial production have led to increased concentration of GHGs and particulate matter in the atmosphere enhancing the **greenhouse effect** and increasing the average temperature at the earth's surface. This is called '**global warming'**. Figure 1 illustrates the greenhouse effect.

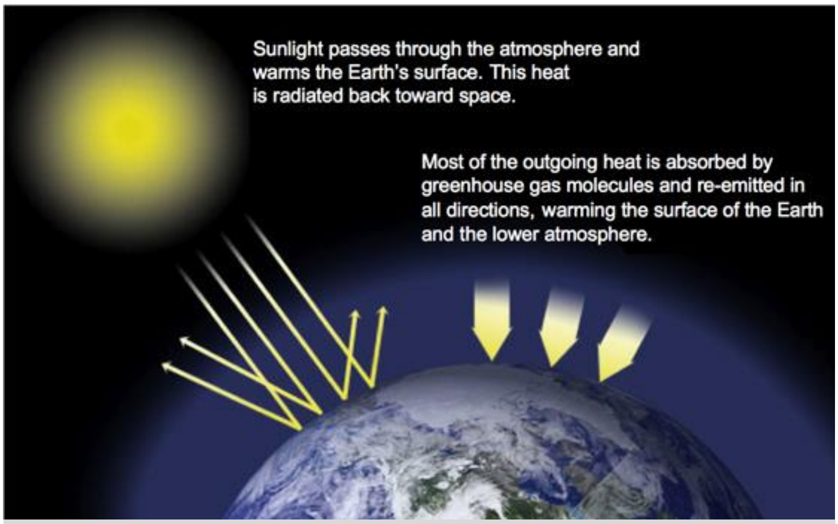

Figure 1: A layer of greenhouse gases – primarily water vapour, and smaller amounts of CO2, CH4, N2O – act as a thermal blanket for the Earth, absorbing heat and warming the surface to a life-supporting average of 15 °C (Global Climate Change: Evidence)

Since the end of the industrial revolution, concentrations of CO_2, produced when fossil fuels (coal, oil, natural gas) are burnt, have risen by over 30%, while CH_4 has approximately doubled. CO_2 molecules can live around 100 years in the atmosphere. Ancient air bubbles trapped in ice enable us to know what the earth's atmosphere and climate were like in the past. They tell us that levels of CO_2 in the atmosphere are higher today than at any time in the past 400,000 years. During ice ages, CO_2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm. But in 2015, CO_2 levels surpassed 400 ppm for the first time in recorded history. This relentless rise in CO_2 shows a remarkably constant relationship with fossil fuel burning, and can be understood based on the simple premise that about 60% of fossil-fuel emissions stay in the air[1]. Today, we stand on the threshold of a new geologic era, which some term the **"Anthropocene"**, one where the climate is determined by human actions and is very different to the one our ancestors knew. If fossil fuel burning continues at a business-as-usual rate, CO_2 will continue to rise and the atmosphere would not be able to return to pre-industrial levels even after tens of thousands of years. Figure 2 shows the scientific measurements and highlights the fact that human beings have a great capacity to change the climate and planet.

[1] Data from National Oceanic and Atmospheric Administration. Some description adapted from the Scripps CO2 Program website, "Keeling Curve Lessons"

Box 1: Gases that cause the Greenhouse Effect

Water vapour: The most abundant greenhouse gas, but importantly, it acts as a feedback to the climate. Water vapour increases as the Earth's atmosphere warms, but so does the possibility of clouds and precipitation, making these some of the most important feedback mechanisms to the greenhouse effect.

Carbon dioxide (CO_2): A minor but very important component of the atmosphere, CO2 is released through natural processes such as respiration and volcanic eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. Human actions have increased atmospheric CO_2 concentration by a third since the Industrial Revolution began. This is the most important long-lived factor of climate change.

Methane (CH_4): A hydrocarbon gas produced both by natural sources and human activities, including the decomposition of wastes in landfills, agriculture, especially rice cultivation, as well as ruminant digestion and manure management associated with domestic livestock. On a molecule-for-molecule basis, methane is a far more active greenhouse gas than carbon dioxide, but also one which is much less abundant in the atmosphere.

Nitrous oxide (N_2O): A powerful greenhouse gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.

Chlorofluorocarbons (CFCs): Synthetic compounds entirely of industrial origin used in a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer. They are also greenhouse gases.

The IPCC provides comparisons of GHG concentrations across time and their impact on climate change.

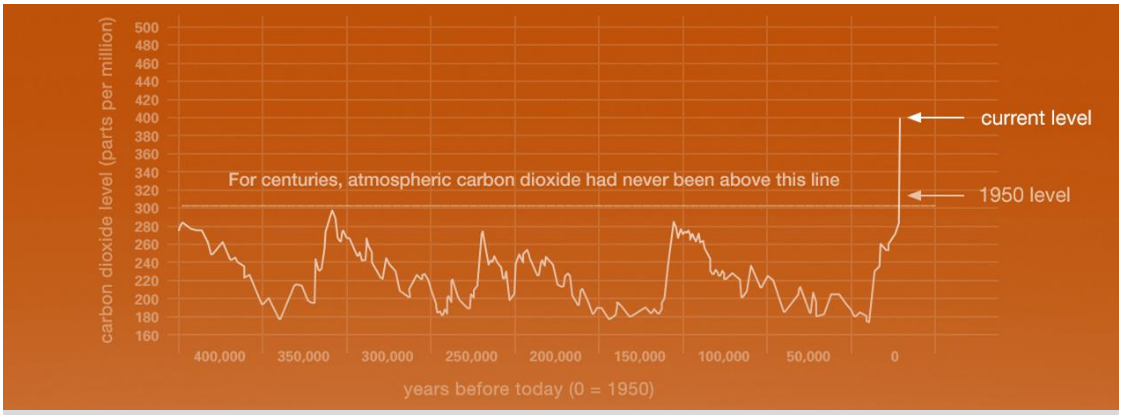

Figure 2: Evidence of atmospheric CO2 increase since the Industrial Revolution based on comparison of atmospheric samples contained in ice cores and more recent direct measurements (Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO2 record)

The surface temperatures of the earth in 2015 were the highest since modern record keeping began in 1880[2]. Globally averaged temperatures in 2015 were higher by 0.13 °C as compared to the previous record set in 2014. At the link you can see a map that displays the changes in global surface temperatures from 1880 through 2015 http://climate.nasa.gov/climate_resources/139/.

Climate observations and trends

Several trends have already been observed and reported in scientific literature. These are attributed to climate change with different degrees of confidence and probability. There are scientific terms with a precise meaning:

Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively using the terms *very low, low, medium, high* and *very high*.

Likelihood is a quantified measure of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations, model results, or expert judgment). The likelihood or probability of some impacts to occur in the future is expressed quantitatively through the following terms:

[2] http://climate.nasa.gov/climate_resources/139/

Term	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

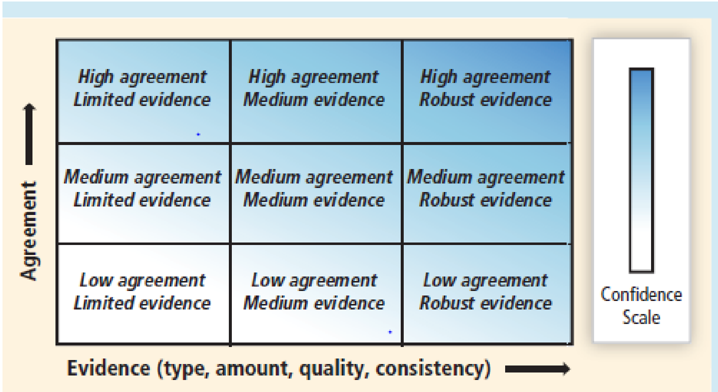

Figure 3: Evidence and agreement statements and their relationship to confidence. The colouring increasing toward the top-right corner indicates increasing confidence. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence (IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change)

The fact that a particular impact is missing or is listed with a 'low confidence' or 'low likelihood' does not mean that it has not occurred but only indicates that the information to support this observation is lacking or low or that observations contradict each other.

What is a climate scenario?

Much of the information on future impacts of climate change is based on scenarios. A scenario is a storyline or image that describes a potential future, developed to inform decision making under uncertainty. Climate scenarios have been used since 1990 with the First Assessment Report of the IPCC and have been refined over the years. Scenarios assume different trajectories of development (population growth, economic development, fuel use, etc.), the related emissions and warming. Co-terminus with the Fifth Assessment of the IPCC, a new, more flexible set of scenarios has been developed called the **'Representative Concentration Pathways'** or RCPs.[3] The four different RCPs describe different climate futures; RCP2.6 is a very optimistic scenario, unlikely to happen while RCP8.5 is a worst case scenario resulting in temperature increase of over 4 °C by 2100. The numbers refer to radiative forcings or the global energy imbalances, measured in watts per square metre, by the year 2100. The second dimension of the scenarios is emission rates which refers to how fast more greenhouse gases are put into the atmosphere, while the third dimension is emission concentrations, measured in parts per millions for each of the greenhouse gases. Each RCP differs greatly in the rate of forcing and emissions. These different rates, or trajectories, form the 'pathways'. Each pathway 'fixes' two values in the year 2100; how much the planet has heated up and the concentration of greenhouse gases (Figure 4).

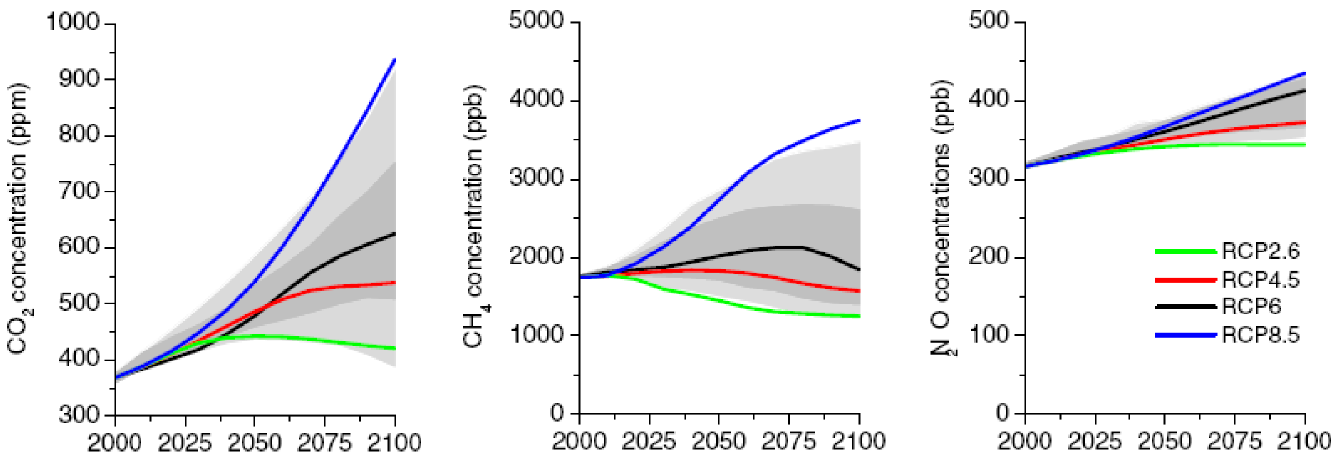

Figure 4: Trends in concentrations of different greenhouse gases across time and in different scenarios (van Vuuren et al., 2011: The representative concentration pathways: an overview)

[3] To know more about this read Chapters 1 and 20 of the Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

The impacts of GHG emissions on temperature rise under the RCP2.6 and RCP8.5 are shown in the first panel of Figure 5. The temperature increase in the near term are similar under all scenarios as we experience the impacts of past emissions but after 2050 a wide divergence is seen based on actions taken now and in the next decade to reduce emissions. The impacts of temperature increase in relation to two baseline periods (1986 – 2005 on the y-axis on the left and pre-industrial levels on the right) are shown in the second panel. Globally 5 key **'reasons for concerns'** from climate change have been identified – the degree to which these are likely to be experienced with each degree of increase in temperature can be seen from the bars.

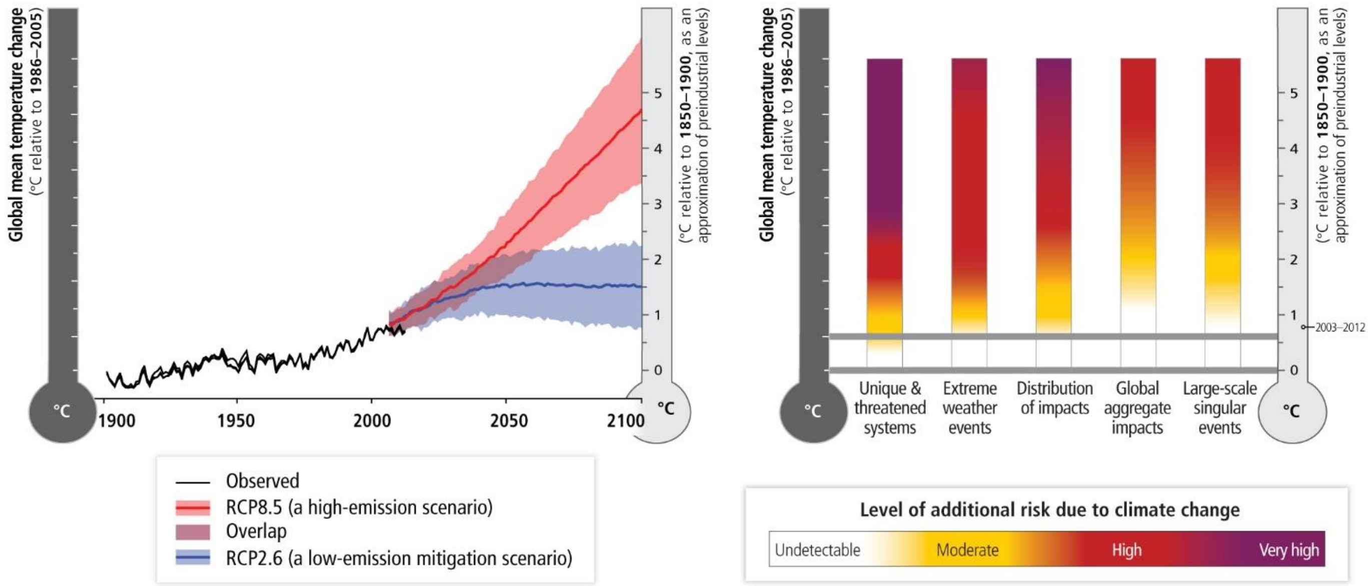

Figure 5: RCPs and temperature, and the impacts on the key reasons for concern (IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change)

Impacts of climate change

In addition to the above 'reasons for concern', a number of other impacts of climate change has been observed in Asia. These are summarised in the IPCC Fifth Assessment Report and are based on the scientific evidence available until 2014. Table 1 presents the degree of confidence with each observed impact and the degree to which it can be attributed to climate change. The IPCC does not undertake or commission primary research, it only assess the robustness of available information and thus observations from countries like Afghanistan, where data is limited, are few. The degree to which an impact can be attributed to climate change is also linked to the availability of supportive research and a 'minor contribution' in the table below may be due to absence of data.

Table 1: Impacts of climate change on landscapes in Asia of particular relevance for Afghanistan (IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change)

Snow and ice	Permafrost degradation in Central Asia and Tibetan Plateau (*high confidence*, major contribution from climate change)
Rivers and lakes	Shrinking mountain glaciers across most of Asia (*medium confidence,* major contribution from climate change) Surface water degradation in parts of Asia, beyond changes due to land use change (*medium confidence*, minor contribution from climate change)
Floods and droughts	Increased flow in four rivers due to shrinking glaciers in the Himalayas and Central Asia (*high confidence*, major contribution from climate change)
Terrestrial ecosystems	Changes in plant Phenology and growth in many parts of Asia (earlier greening), particularly in north and east (*medium confidence*, major contribution from climate change) Distributional shifts of many plant and animal species upwards in elevation or polewards, particularly in the north of Asia (*medium confidence*, major contribution from climate change)
Food production and livelihoods	Negative impacts on aggregate wheat yields in South Asia, beyond increase due to improved technology *(medium confidence,* minor contribution from climate change)

Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions. Area encompassed by monsoon systems will increase. Monsoon onset dates are likely to become earlier or not to change much. Monsoon retreat dates will likely be delayed, resulting in lengthening of the monsoon season in many regions. Due to the increase in moisture availability, ENSO [El Niño Southern Oscillation] related precipitation variability on regional scales will likely intensify.

More frequent hot and fewer cold temperature extremes are predicted over most land areas on daily and seasonal timescales as global mean temperatures increase. Heat waves are likely to occur with a higher frequency and duration. Occasional cold winter extremes will continue to occur. In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation is likely to increase. While monsoon winds are likely to weaken, monsoon precipitation is likely to intensify due to the increase in atmospheric moisture. Five to 25% increase in number of extreme precipitation days greater than 5 mm is projected by 2100. About 25% increase in extreme precipitation days increasing by more than 5 days is projected in most part of India. Consecutively, increase in number of consecutive dry days is projected in all parts of the globe.

Climate trends for Afghanistan

Afghanistan has an arid and semi-arid continental climate with cold winters and hot summers. The lowland plains in the south of Afghanistan experience extreme seasonal variations in temperature, with average summer temperatures exceeding 33°C and mean winter temperatures of around 10°C. Much of the country is at very high altitude and experiences much lower temperatures all year round, with average summer temperatures not exceeding 15°C, and winter temperatures below zero in the highest regions.

The country is characterised by large areas with little to no precipitation; that which does occur falls mostly as snow on high mountains from winter storms (of Mediterranean origin) between November and April with peaks in February/March. The snow season varies considerably with elevation. The Asian summer monsoon system helps to keep rainfall low over Afghanistan. Dust storms are a significant part of the climate system associated with northerly winds in warm months.

These climate factors and the socio-economic conditions of Afghanistan make it one of the most vulnerable countries to the adverse impacts of climate change. Afghanistan's national communication to the UNFCCC has documented an increase of 0.6°C in the country's mean annual temperature since 1960. Based upon recent climate observations, precipitation patterns have decreased during springtime (March-May) by approximately 40.5 mm; however, the total annual precipitation has only slightly decreased by approximately 30 mm since there is a slight increase in precipitation from June until November. This implies that Afghanistan is already beginning to experience the initial adverse impacts of climate change.

Climate Projections

Recent climate projections, based on regional climate models and RCPs, indicate that Afghanistan will face an overall strong increase in mean annual temperature, considerably higher than global mean projections, when compared to a baseline period 1986-2006. More specifically, under the "optimistic" scenario (RCP4.5), the mean of the models projects a warming of approximately 1.5°C until 2050 and of approximately 2.5°C until 2100. For the "pessimistic" scenario (RCP8.5), the models project an extreme warming of approximately 3 °C until 2050, with further warming up to 7°C by 2100. Under both scenarios there are regional differences, with a higher temperature increases at higher altitudes compared to the lowlands. Warming is most rapid in spring/summer with this trend being marked in the north and the central plains of Afghanistan. These increases are also consistent with the broad regional observed temperature trends in Central Asia. All projections indicate substantial increases in the frequency of days and nights that are considered 'hot' in current climate, especially during summer months. Up to 2030s, the amount of warming is not sensitive to global emission scenarios. The range of potential annual temperature increases is noticeably influenced by global emission scenarios reflecting the high degree of vulnerability of the country to global trends. The warming trend will lead to higher evaporation rates causing further soil erosion and land degradation. Prolonged droughts and scarcity of water and pastures have led to large internal displacements in the past decades. This trend is likely to continue and intensify.

For **precipitation** a significant mean decrease of precipitation during springtime (March-May) for the North, the Central Highlands and the East for both scenarios from 2006 until 2050 between 5 to 10% is seen. This decrease is offset by a slight increase of precipitation during autumn and wintertime (October-December) in these regions. For the Hindu Kush area, a significant and substantial increase in precipitation during the winter season of approximately 10% is seen, whereas during spring season precipitation is projected to stay stable. For the arid South of the country, the models do not project significant trends for precipitation. The decrease of precipitation during spring is particularly relevant since during these months the main plant growth for agricultural production takes place. In addition, the decrease is projected to take place in the regions with the highest agricultural productivity of Afghanistan (East, North, and Central Highlands). Climate change is making water resources scarcer due to widespread mass losses from glaciers and reductions in snow cover (because Afghanistan is already extremely vulnerable to drought and floods, the consequences of climate change on water security is a serious concern).

In combination with the overall increase in temperature and the related increase in evapotranspiration across the country, this will most likely negatively impact the hydrological cycle, agricultural productivity, and availability of water resources. Climatic changes are also likely to impact upon the spread of water, food and vector-borne diseases, presenting considerable health risks to both urban and rural populations. Finally, the aforementioned climate-induced risks and challenges can enhance social inequalities, poverty, and food insecurity causing considerable and fundamental threats to human life, livelihoods, property, political stability, the economy, and the environment in Afghanistan.

Conclusion

Climate change impacts regions, livelihoods and communities differentially based on the current vulnerabilities, livelihood strategies and their capabilities. Afghanistan faces many risks both in the immediate and long terms. All development interventions must therefore take into account future climate scenarios and contribute to building greater adaptive capacities and resilience. A disaster and climate risk screening of development interventions would avoid that projects 'lock in' the country to activities that are no longer feasible in a changed climate and hazard context. Measures for DRM to adapt and mitigate climate change impacts are introduced in the following Modules (4, 5, 6, 9 and 10) while Module 7 provides an introduction to risk assessment and planning tools.

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Federal Department of Foreign Affairs FDFA
Swiss Agency for Development and Cooperation SDC

Further readings:

- NASA's Global Climate Change website. Causes. Available at: http://climate.nasa.gov/causes/
- NASA's Global Climate Change website. Global warming from 1880 to 2015. Available at: http://climate.nasa.gov/climate_resources/139/
- HELVETAS Swiss Intercooperation, 2014: Climate Change Impacts on Asia: Findings from the IPCC 5 Assessment Report.
- Wayne G.P., 2013: The Beginner's Guide to Representative Concentration Pathways. Available at: http://www.skepticalscience.com/docs/RCP_Guide.pdf