Chapter 9
Looking at Climate Change and its Socio-Economic and Ecological Implications through BGC (Bio-Geo-Chemical Cycle)-Lens: An ADAM (Accretion of Data and Modulation) and EVE (Environmentally Viable Engineering Estimates) Analysis

J. S. Pandey

Abstract Viewing climate change merely as a change in temperature or humidity levels is a very narrow way of looking at the problem, which in essence has a much wider implication and ramification. Transmission and distribution of impacts under interactive and integrated influence of climate change and environmental pollution is an important area of research, which helps in quantifying human and ecosystem health risks. This also helps ultimately in converting them into the real economic terms - financial benefits accrued or costs incurred. Moreover, alterations and aberrations in temperature and humidity are very closely linked with significant perturbations in bio-geo-chemical cycles (BGCs). In essence, this means that climate change problem should ideally be viewed as a significant perturbation in BGCs. It is now gradually getting understood and established that alterations in land use and cover changes also affect (very significantly) the transmission and distribution dynamics of various diseases. The need of the hour, therefore, is to study the directions of these alterations and quantifications of their implications and impacts through ADAM (Accretion of Data and Modulation) and EVE (Environmentally Viable Engineering Estimates) Analysis. While discussing above-mentioned issues in the present paper, some case studies are also presented.

Keywords Carbon foot print · Ecological footprint · Life style solutions · Climate change

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9.1 Introduction

Whether scientific research should follow a policy driven approach or a curiosity driven approach? This question assumes its significance and importance especially in view of the financial crunch and continuously depleting global natural resources. Transmission and distribution of impacts under interactive and integrated influence of climate change and environmental pollution is an important area of research, which helps in quantifying human and ecosystem health risks. This also helps ultimately in converting them into the real economic terms – financial benefits accrued or costs incurred. The real scientific challenge today is to find out the ways and means of quantifying the following scientific facts:

- Intricate interaction between climate change and environmental pollution, and their impacts in terms of human and ecosystem health
- Alterations in land cover, biodiversity, air, water and soil pollution, and their implications on climate change impacts and on availability of food-items and nutrients
- Impacts of above-mentioned alterations on disease transmission and dynamics

In this context, it is important to reiterate that forests have one very important ecological role i.e. they regulate all the natural bio-geo-chemical cycles – for instance, carbon cycle, water cycle, nitrogen cycle and phosphorus cycle etc. One very pertinent fact which should not be overlooked is the fact that alterations and aberrations in temperature and humidity are also very closely linked with significant perturbations in bio-geo-chemical cycles (BGCs).

In essence, this means that climate change problem should ideally be viewed as a significant perturbation in BGCs. Viewing climate change merely as a change in temperature or humidity levels is a very narrow way of looking at the problem, which in essence has a much wider implication and ramification. Ideally, there is no such anthropogenic activity (be it residential, commercial or industrial), which does not involve alterations in surrounding ecosystems and bio-geo-chemical cycling. Moreover, pollution generation can simply be construed as a land-use impact. Therefore, a given shift in land use pattern would essentially result in a consequential shift in pollution levels (air, water and soil) and generation of various green house gases. It is now gradually getting understood and established that alterations in land use and cover changes also affect (very significantly) the transmission and distribution dynamics of various diseases. The need of the hour, therefore, is to study the directions of these alterations and quantifications of their implications and impacts through ADAM (Accretion of Data and Modulation) and EVE (Environmentally Viable Engineering Estimates) Analysis. While discussing above-mentioned issues in the present paper, some case studies are also presented.

9.2 Climate Change

Long-term changes in the average weather conditions, which are unique combinations of factors like temperature, precipitation and wind, denote Climate Change. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), our climate is undergoing significant changes as a result of day by day increasing greenhouse gas (GHG) emissions from several anthropogenic activities. GHG's are those gases in the atmosphere that act together like a glass roof around the earth. This glass roof (imaginary), traps in heat that would have otherwise escaped into space. This heat-trapping-effect is known as the "greenhouse effect".

Amongst these GHGs, Carbon dioxide (CO_2) happens to be the most significant and prevalent GHG. It is mostly released due to the burning of fossil fuels like coal, oil and natural gas. Methane (CH_4), sulphur hexafluoride (SF_6), nitrous oxide (N_2O), nitrogen trifluoride, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) were later on included in the Kyoto Protocol. Kyoto Protocol, which was signed on 11th December, 1997 and came into force on 16th February, 2005, is an international agreement for emission reduction. Chlorofluorocarbons (CFCs) are being phased out under the requirements of Montreal Protocol (http://www.carbonneutral.com/resource-hub/climate-change-summary).

9.3 Global Warming and Climate Change

In simple terms, global warming and climate change are results of continuously rising global average temperatures. The rise in global average temperature is caused mainly due to increase in many green house gases - carbon dioxide being the main culprit. Green house gases are mainly being emitted through various anthropogenic activities, which involve fossil fuel burning. Here it is also pertinent to note the difference between the times involved in the deposition of fossil fuels and that in their consumption. It would amount to several billion years. Temperature being one of the key determinants of weather and climate, a global warming automatically converts into unpredictable changes in local, regional and global weather-patterns. And, over a long period of time, the event automatically converts into climate change (http://www.globalissues.org/print/article/233).

9.4 Main Indicators of Climate Change

According to the National Oceanic and Atmospheric Administration (NOAA), there are 10 main indicators of climate change. 7 of these indicators (Tropospheric temperature, temperature over oceans, sea surface temperature, oceanic heat content, temperature over land, sea level and humidity) are expected to increase as they are already doing and 3 indicators (glaciers, snow cover and sea ice) should show a declining trend. These events are already being witnessed.

9.5 Green House Effect

Energy from the sun heats the earth's surface, Earth radiates some of this energy back to the space. Part of the energy is absorbed by the green house gases (water vapor, carbon dioxide, and other gases) present in the earth's atmosphere. They retain heat in the atmosphere same as the way glass panels of a greenhouse does. This is what drives the earth's weather and climate. That's the reason why these gases are known as greenhouse gases (GHG).

There are 3 main GHGs such as:

- Carbon dioxide (CO_2)
- Methane (CH_4) with global warming potential (GWP) almost 20 times higher than carbon dioxide
- Nitrous oxide (N_2O).

These are emitted through both natural and man-made sources. However, emissions through man-made sources have recently increased substantially and have ultimately become serious cause of concern. In addition, there are some GHGs which have only anthropogenic sources of emissions. They are:

- Hydrofluorocarbons (HFC_s)
- Perfluorocarbons (PFC_s) and
- Sulphur hexafluoride (SF_6).

Water vapor is also considered a greenhouse gas.

9.6 Climate Change and Bio-Geochemical Cycling

Bio-geochemical cycles (Carbon cycle, water cycle, nitogen cycle, phosphorus cycle and sulphur cycle etc.), green house effect, global warming and climate change are all interlinked. All the time, we are mining coal and extracting oil from the Earth's crust. Subsequently, we are burning these fossil fuels for various industrial, commercial and residential activities such as energy production, transportation, cooling, heating, cooking, and manufacturing. Ultimately the rate at which fossil fuels are being burnt, GHG_s are being emitted into the atmosphere is much higher than the rate at which GHGs are removed from the atmosphere. This leads to continuous GHG-build-up in the atmosphere.

On the other hand, forests, which are very effective filters or sinks for many GHG_s (mainly CO_2) are continuously being cleared for various agricultural, residential, commercial and industrial purposes. This results in doing away with one

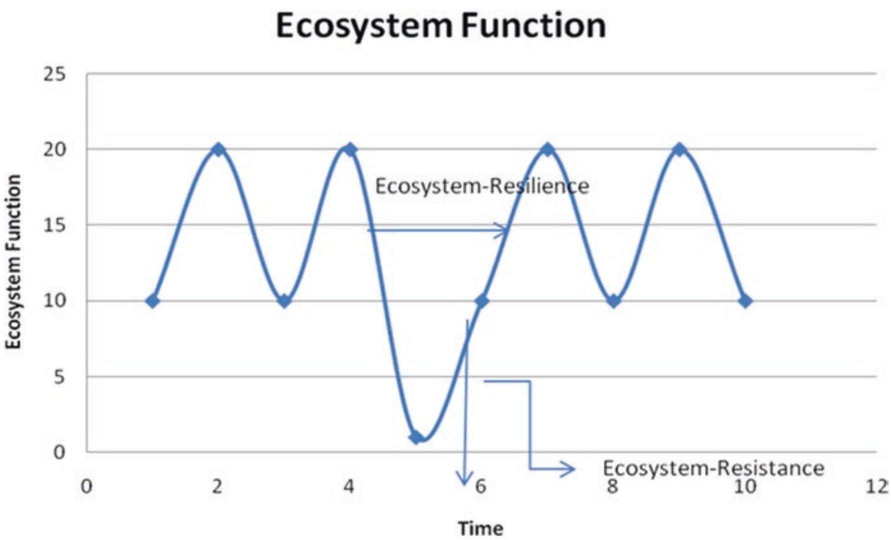


Fig. 9.1 Ecosystem resistance and resilience

of the most effective sinks of pollution and consequently enhancing GHG-build-up in the atmosphere. Mainly because of these reasons, GHG-concentrations today are much higher than what they were several decades and centuries back.

There could be a very simple analogy, which would make us understand the problem related to GHG-built-up in the atmosphere. GHGs' requirement and presence in the atmosphere can be construed as that of salt in our food. A given amount of salt is essential for providing good taste to our food and is also essential for our health. But if we add too much salt into our food, it not only spoils the taste of our food but would also spoil our health leading to diseases like hypertension etc.

The other problems with human induced land use changes and consequent GHG-emissions are that they have recently become so rapid that the surrounding ecosystems are not able to adjust with respect to them. In short, it affects ecosystem's resilience and resistance (Fig. 9.1).

9.7 Impact of Life Style Changes on Carbon Cycle and Climate Change

There are always some issues, queries and questions raised about the fact that since the climate has been always and continuously changing, why there should be so much fuss about it now. The main difference lies in the rapidity of weather related aberrations observed recently. And some of the significant indicators, which point towards the human footprint on climate change, can be delineated as follows:

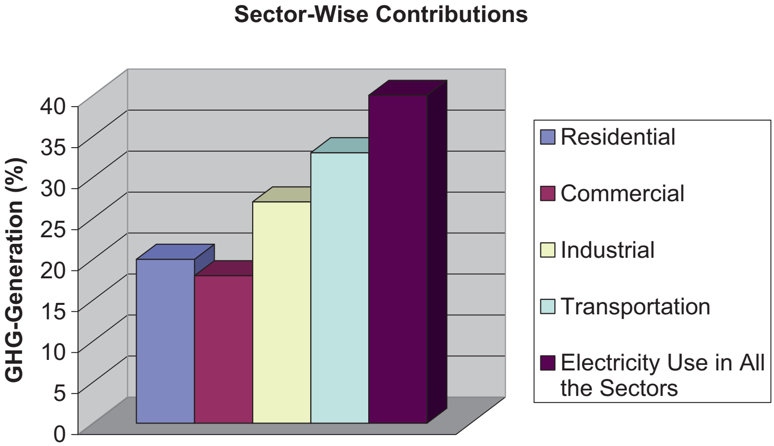


Fig. 9.2 Sector-wise CO_2-emissions

- Less oxygen in the air
- Shrinking thermosphere
- Elongation of tropopause
- More fossil fuel carbon in the air, and
- More fossil fuel carbon in the coral reef

Ultimate solutions to climate change problems (Adger et al. 2005) lie in regulating and controlling three key sectors: production, consumption and life-style. The third one automatically takes care of the first two, because our production and consumption patterns and trends depend directly on our life-styles. Food, clothing and shelter are our primary requirements and they all contribute significantly to increasing concentrations of Greenhouse Gases (GHGs) (USEPA 2005; Pandey et al. 1997) and ultimately to climate change problem. The present paper illustrates some model development exercises based on realistic and relevant parameters, which are easy to measure and monitor. Subsequently, the article also highlights research-needs, which need to be pursued in various educational and research Institutions so as to gradually make every citizen of the society environmentally aware and responsible. Figure 9.2 provides the percentage contribution from various sectors (industrial, commercial, residential and transportation) towards GHG-generation (http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html#emissions).

9.8 Carbon Foot-Printing (CF) and Ecological Foot-Printing (EF)

Carbon Foot-printing (CF) and Ecological Foot-printing (EF) (http://www.ecologicalfootprint.com; Rees and Wackernagel 1996, 1999; Mishra et al. 2008) are some of the recent Environmental Impact Assessment tools. They (CF & EF) not only help in understanding and quantifying impacts due to various activities including solid waste disposal, waste water treatment, air pollution control etc., but also in evolving appropriate cost-effective environmental management plans. Moreover, there is a significant awareness in respect of greenhouse gases (GHGs), global warming, climate change and carbon footprints (CFs). Institutions like US Environmental Protection Agency (USEPA) and Water Utility Climate Alliance are already working vigorously in this direction. CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide) and fluorinated gases such as hydro fluorocarbons, per fluorocarbons and sulfur hexafluoride are the main GHGs, which contribute significantly to total CF. These GHGs have widely different global warming potentials according to the Intergovernmental Panel on Climate Change (IPCC 2006). Activities that lead to GHG-emissions are said to be ***carbon-positive***, while those which remove GHGs from the environment are known as ***carbon-negative*** or carbon-sinks. When GHG-emissions equal GHG-assimilation or absorption, the activities are known as ***carbon-neutral.***

9.9 CF (Carbon Footprint) – Calculators

CF-calculators (Padgett et al. 2008) are very frequently being used for estimating GHG (CO_2-e) emissions. However, not all CF-calculators give same or similar results. The differences amongst them could be as high as 5–6 million MT per year per individual. Generally, the kind of inputs, these CF-calculators require can be summarized as follows:

- Electricity / Energy / Oil / Natural Gas / Propane / Kerosene / Wood consumption and related emission factors
- Waste generation and related emission factors
- Number of individuals / institutions / activities (as the case may be)
- Distance covered in transportation (flight / rail / road) and related emission factors
- Number of vehicles and their emission factors
- Use of air conditioners and their emission factors

And, the variations in CF-results are normally attributed to the following factors:

- Methodologies
- Individual Behavioral Features
- Conversion and Emission Factors, and
- Lack of Transparency

The greatest uncertainty, however, is associated with emission (conversion) factors. Most of the calculators do not display or explicitly explain the methodologies behind these factors. As a result, they land up using significantly different emission factors. And since these calculators are supposed to influence and guide the citizens and policy makers for taking appropriate pollution (carbon) reduction measures and strategies, these uncertainties and variations cannot be ignored. However, even with these uncertainties and sources of errors, these calculators do generate awareness amongst common masses about environmental protection and conservation.

9.10 Ecological Footprint

The ecological footprint (EF) [http://www.ecologicalfootprint.com/] is a broad measure of resource use which highlights the areas where consumption is exceeding environmental limits. It mainly depends on the following parameters (http://steppingforward.org.uk/calc/):

1	Travelling (Transport)
2.	Living Space (Residential)
3.	Sharing of Apartment (Life Style)
4.	Heating / Cooling Bills (Energy/Electricity Consumption)
5.	Use of Electricity (Type)
6.	Energy Conservation Measures
7.	Food Habits
8.	Food Imports/Exports
9.	Waste Generation
10.	Type of Waste

9.11 ADAM and EVE Applications: Some Case Studies

In the following section, some results from ADAM and EVE applications to different areas like Paper Industry (Fig. 9.3), Waste Water Treatment System (Figs. 9.4 & 9.5), Himalayan Ecosystem (Fig. 9.6), Various Indian Coastal Zones (Fig. 9.7) and Mithi River Ecosystem (Fig. 9.8) are presented for illustration.

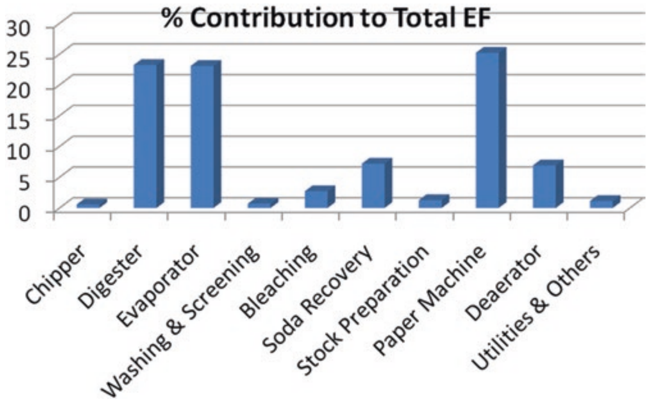


Fig. 9.3 Paper industry

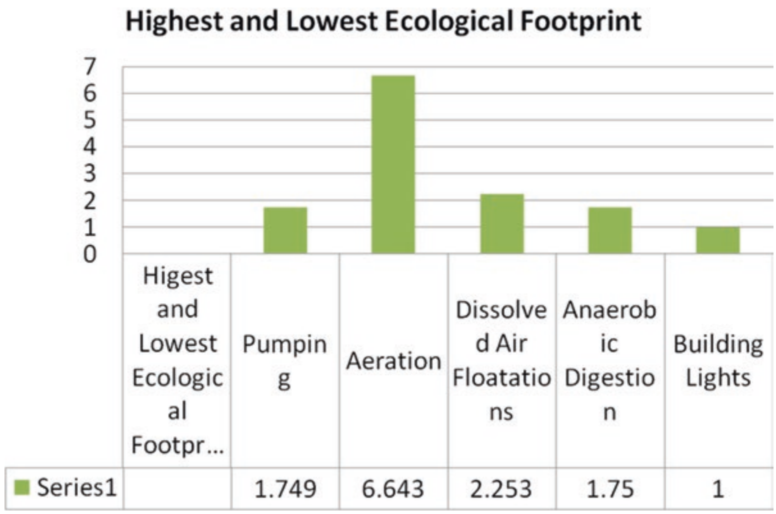
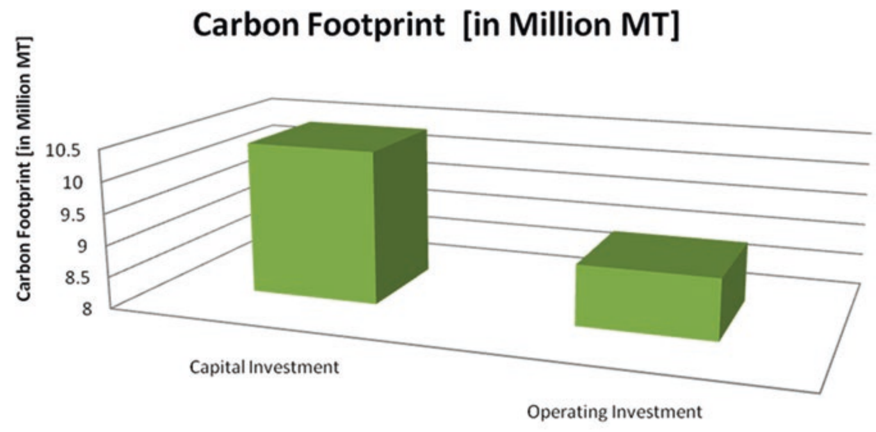


Fig. 9.4 Waste water treatment

9.12 Need for Urgency

The following areas need immediate attention:

- Emission reduction targets need to be given the highest priority.
- Nationally Appropriate Mitigation Actions (NAMA) should focus on enhancing energy efficiency as the most important means for reducing GHG-emissions.
- Investment in energy efficient programmes in developing countries should need continuous and consistent support from well developed countries.



	Capital Investment	Operating Investment
Carbon Footprint [in Million MT]	10.417	8.951

Fig. 9.5 Investment in waste water treatment system

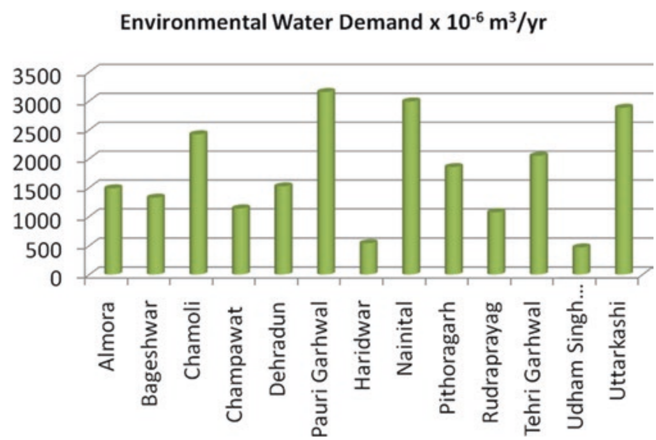


Fig. 9.6 Himalayan ecosystem

- Continuous monitoring and energy / environment audits are the most important segments of any well-intentioned and effective environmental management plan.

In short, the environmental audit process should be guided through the following diagram (Fig. 9.9).

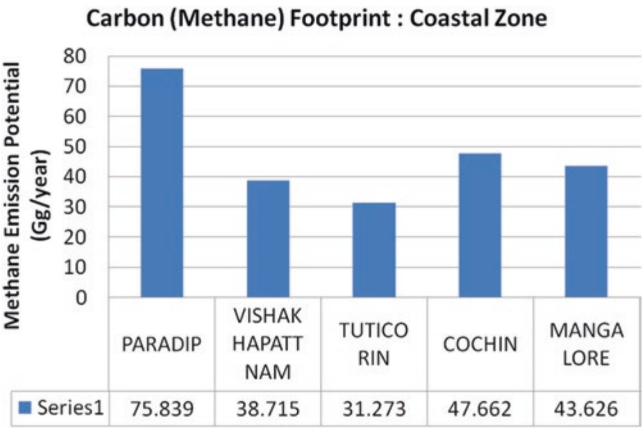


Fig. 9.7 Coastal zone

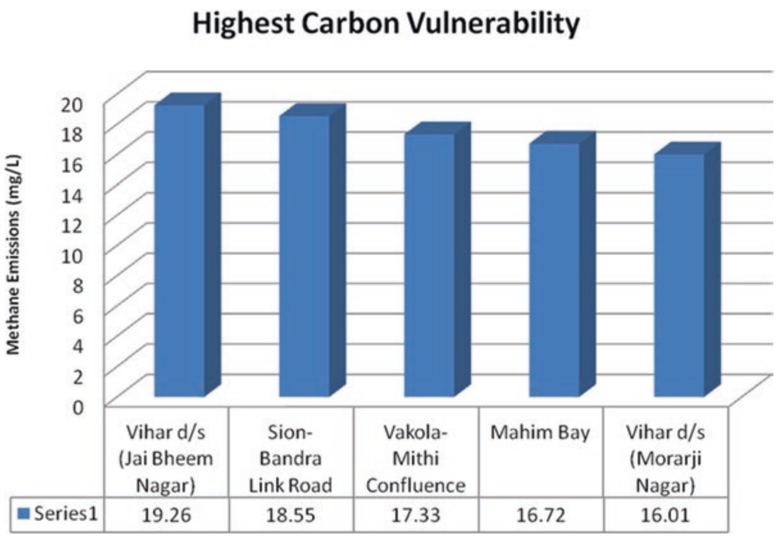


Fig. 9.8 River ecosystem

9.13 Conclusion

Ultimate solutions to climate change problems lie in regulating and controlling the three key sectors: production, consumption and life-style. In fact the third one automatically takes care of the first two, because our production and consumption patterns and trends depend directly on our life-styles. This boils down to the fact that key to climate change mitigation lies in our life styles. Food, clothing and shelter are our primary requirements and they all contribute significantly to

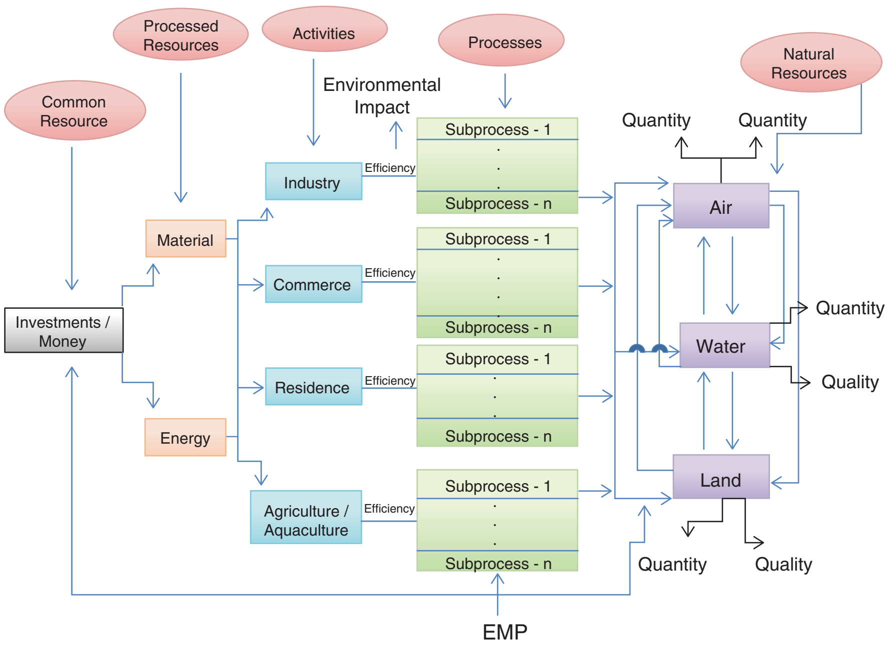


Fig. 9.9 Environmental and ecological auditing (Flow diagram)

increasing concentrations of Greenhouse Gases (GHGs) and ultimately to climate change problem.

The present paper illustrates some model development exercises based on realistic and relevant parameters, which are easy to measure and monitor. Subsequently, the article also shows what kind of researches need to be pursued in various educational and research Institutions so as to gradually make every citizen of the society environmentally aware and responsible. In short, the presentation discusses and recommends the kind of activities which need regular pursuance, refinement, modification and application in regard to evolving site-specific, region-specific and ecosystem-specific environmental management plans aimed at combating the climate regulated environmental crisis which is unfolding before us every day with a newer dimension.

Inter alia, the article deals with the kind of research, which is needed in the area of Climate Change. Side by side, these researches need to be extended and pursued further so as to strike a balance between ecology and economy. Future exercises are needed, which should aim at the dynamics of Ecological Footprints (Pandey et al. 2001a, b); analysis of Environmental Risks (Pandey and Joseph 2001) by way of developing models which deal with the issues like Temporal Risk Gradients (TRG) (Pandey et al. 2001b) and Ecological Economics of Natural Resources (Pandey et al. 2004). There is also a need for quantifying region-specific-emission factors for different GHGs (Pandey et al. 2007). On the basis of these emission factors, region-specific ecosystem health (Pandey and Khanna 1992) and human health risk assessment (Pandey et al. 1992, 1993, 1994, 2005) can be carried out.

Subsequently, appropriate region-specific environmental management plans can be developed. Ecology works very much on the concepts of species-specific, ecosystem-specific and process-specific bio-rhythms (Pandey and Khanna 1995). It has a perfect analogy with the way a musical concert or consortia works or in terms of Electronics Engineering, the way an integrated circuit (IC) works. All these features are embedded in Ecological Engineering.

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