
Introduction to Environmental Management and Services

1.1. Introduction

Environmental management is an activity involved with social management that regulates human activities based on systematic access and information coordination skills for environmental issues. Environmental management is related to people, toward sustainable development and sustainable use of resources. In environmental management, some subjects should be integrated for optimal controlling and monitoring such as (1) environmental components, (2) environmental quality, (3) environmental pollution and (4) data services for the environment.

Environmental quality is a set of properties and characteristics of the environment, either generalized or local, as they impinge on human beings and other organisms. It is a measure of the condition of an environment relative to the requirements of one or more species and/or to any human need or purpose (Johnson *et al.* 1997). Environmental quality includes the natural environment as well as the built environment, such as air and water purity or pollution, noise and the potential effects which such characteristics may have on physical and mental health (EEA). In principle, environmental quality can be measured in terms of the value the people place on these non-waste receptor services or the willingness to pay.

Many parameters of the environment (air, water, soil and biome) should be collected to assess the environmental quality and propose standards for controlling the environmental quality. We can look at water quality parameters such as pH, T,

color, turbidity, TSS, TDS, DO, COD, BOD, bacterial parameters; air quality parameters such as SO₂, CO, NO₂, O₃, TSP, PM₁₀, PM_{2.5}, Pb; and soil quality parameters such as As, Cd, Pb, Cr, Cu, Zn, organic pollutants. The biome includes plants, animals and microorganisms; and can maintain and develop via ecological systems and nutrient cycles.

Human activities and natural occurrences, which release many kinds of pollutants, must be quantified and qualified through the environmental parameters. Over-release of pollutants into the environment causes the pollution which induces the environmental composition to break down and malfunction. However, nature has efficient functions to treat and overcome the stress of pollution by converting the pollutants into nutrients and energy. Therefore, understanding the functions of nature (the environment), people can monitor and control the released pollution against environmental quality parameters, and then issue the environmental standards for each activity and release.

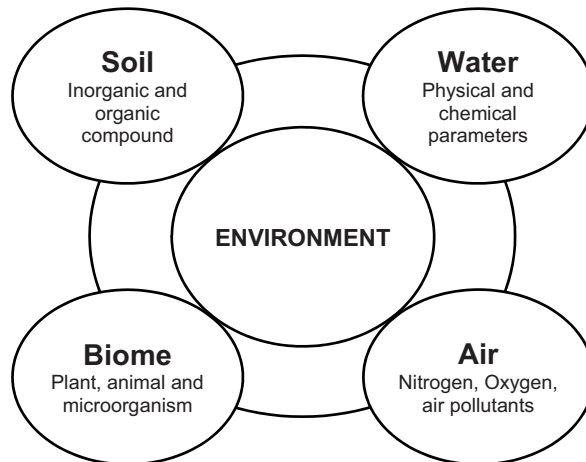


Figure 1.1. *Environmental components*

1.2. Environmental components

Global environmental components can be generally divided into four main compositions: lithosphere, atmosphere, hydrosphere and biosphere. Each sphere interacts with the others to drive the dynamic change of the Earth. The description of each sphere and its interactions are summarized in the following subsections.

1.2.1. Lithosphere

Lithosphere refers to the rock and rigid layers of the Earth. The crust of the Earth covering the entire planet is around 5–50 km in depth (see also Figure 1.2(a)). In particular, in terms of the environment, the lithosphere is also known as soil layers (Bleam 2017). Soil composition is determined by its parent materials, as well as the weathering of rocks and sediments. Soil composition constrains the biological availability for living organisms. Common elements found in soil are mainly oxygen, silicon and aluminum (see Figure 1.2(b)). Most minerals are formed by two or more elements during the solidification of magma or lava and/or recrystallization by weathering.

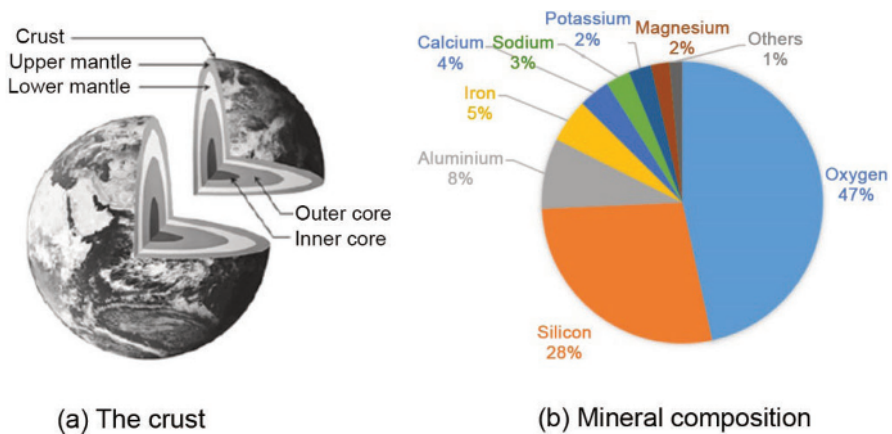


Figure 1.2. The crust structure and its mineral composition (adapted from: Osman 2013). For a color version of this figure, see www.iste.co.uk/laffly/torus3.zip

1.2.2. Atmosphere

Atmosphere refers to the layer of air and gases surrounding the Earth. It consists of a mixture of the gases (by volume): nitrogen (78.084%), oxygen (20.9476%), water vapor (variable), carbon dioxide (0.0314%) inert gases such as argon (0.934%) and some other rare gases (Osman 2013). Atmospheric layers are divided into four layers depending on the temperature: troposphere, stratosphere, mesosphere and thermosphere. Among these layers, the troposphere is considered the most important and relevant to living organisms including humans. The layer has around 75% of the total mass of the atmosphere and most of the atmospheric elements are found here. Atmospheric composition plays an important role on the radiation budget to cool down or heat up the Earth's surface (Schlager *et al.* 2012). The composition of gases in the atmosphere is slightly altered by chemical reactions.

1.2.3. Hydrosphere

The hydrosphere is the water portion of the Earth's surface as it is distinguished from the solid part (in the lithosphere) and atmosphere (Glazovsky 2009). It includes the waters of oceans, seas, rivers, lakes, swamps and marshes, as well as soil moisture, underground water, water in the atmosphere and water in glaciers, ice and snow cover, as well as in all living organisms.

The distribution of water on the Earth's surface is extremely uneven. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69% resides in glaciers, 30% underground and less than 1% is located in lakes, rivers and swamps. Another way of looking at this is that only 1% of the water on the Earth's surface is usable by humans, and 99% of the usable quantity is situated underground (Figure 1.3).

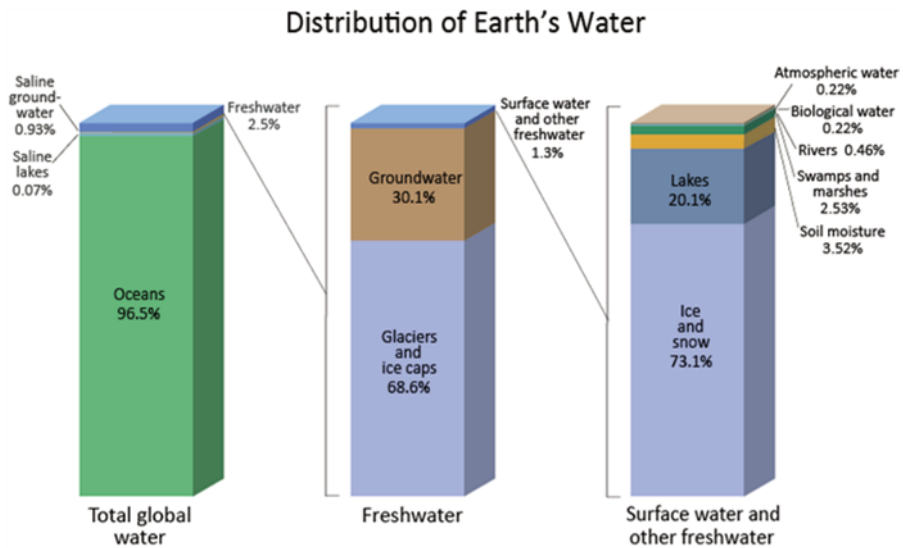


Figure 1.3. *The distribution of Earth's water (adapted from: Gleick 1993).*

For a color version of this figure, see www.iste.co.uk/laffly/torus3.zip

Because Earth's water is present in three states, it can get into a variety of environments. The movement of water around the Earth's surface is the hydrologic (water) cycle (see Figure 1.4). Water changes from a liquid to a gas by evaporation by the sun to become water vapor. In surface water, only the water molecules evaporate; the salts remain in the ocean or freshwater reservoir.

The water vapor remains in the atmosphere until it undergoes condensation to become droplets. The droplets gather in to clouds that are blown about the globe by wind. As the water droplets in the clouds collide and grow, they fall from the sky as precipitation. Precipitation can be rain, hail or snow. Sometimes precipitation falls back into the ocean and sometimes it falls onto the land surface.

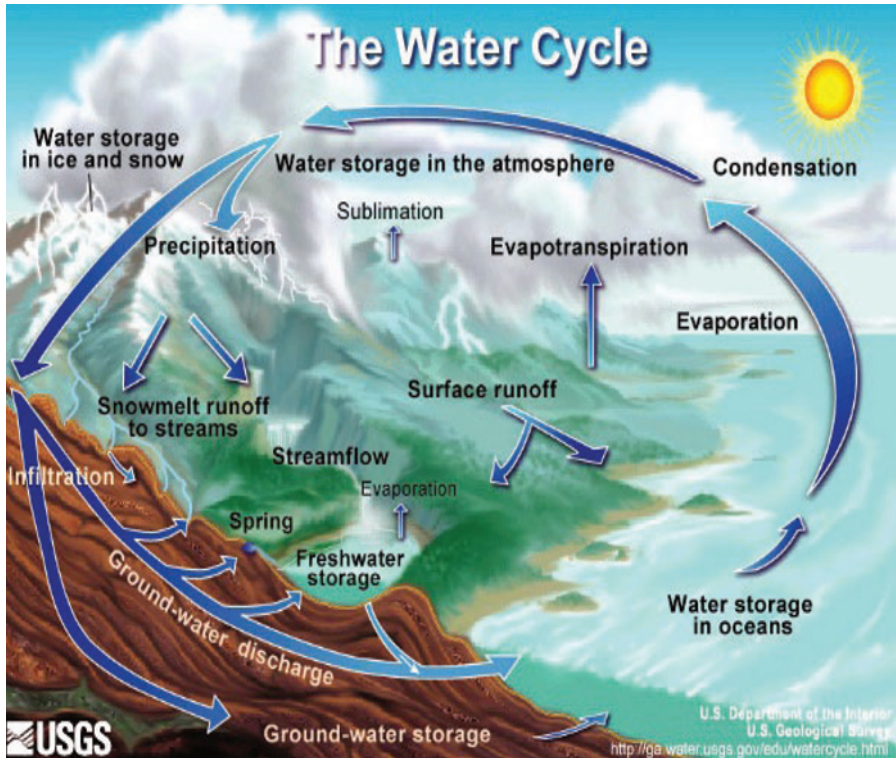


Figure 1.4. *The water cycle (source: USGS 2018). For a color version of this figure, see www.iste.co.uk/laffly/torus3.zip*

1.2.4. Biosphere

The biosphere is the layer of the Earth including the hydrosphere, the lowermost part of the atmosphere, and a portion of the uppermost lithosphere (see Figure 1.5). Part of the Earth's surface and atmosphere contains the entire terrestrial ecosystem and extends from the ocean. It contains all living organisms and the supporting media: soil, subsurface water, bodies of water and air. This sphere is also called the ecosphere.

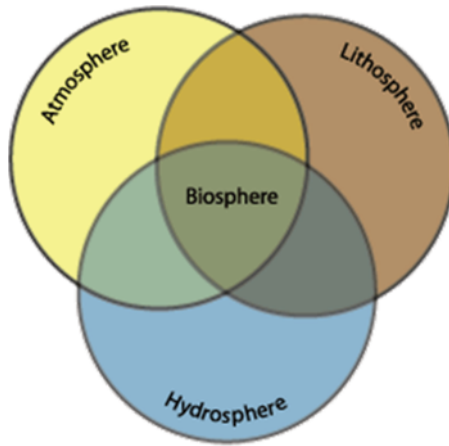


Figure 1.5. *Interactions of environmental components (adapted from: Osman 2013). For a color version of this figure, see www.iste.co.uk/laffly/torus3.zip*

As a key component of earth systems, the biosphere interacts with and exchanges matter, including energy, with the other spheres. This helps to drive the global biogeochemical cycling of carbon, nitrogen, phosphorus, sulfur and other elements. The biosphere is the “global ecosystem”, comprising the totality of biodiversity on Earth and performing all manner of biological functions: photosynthesis and respiration, decomposition, nitrogen fixation and denitrification. Interaction of the biosphere is very dynamic, undergoing strong seasonal cycles in primary productivity and various biological processes driven by the energy captured by photosynthesis.

1.3. Environmental pollution

What is pollution? Pollution occurs when pollutants contaminate the natural surroundings, which brings about changes that adversely affect our normal lifestyles. Pollutants are the key elements or components of pollution, which can be any substance or form of energy. Pollution disturbs our ecosystem and the balance in the environment. With modernization and development in our lives, pollution has reached its peak, causing changes in the environment and human disease.

1.3.1. Air pollution

Air pollution affects our environment and human health. Pollution occurs in different forms: gas, liquid, solid, radioactive, noise, heat/thermal and light. Every

form of pollution has two sources of occurrence: the point and the non-point sources. The point sources are easy to identify, monitor and control, whereas the non-point sources are hard to control.

Effects of pollution are (1) Environment Degradation: Environment is the first casualty for an increase in pollution, whether in air, water or land. It can lead to many other problems which may be local, regional or global problems such as global warming, ozone depletion, acid rain, eutrophication or the spread of toxic chemicals. Some examples are the emission of **greenhouse gases**, particularly CO₂, that is leading to global warming, or chlorofluorocarbons (CFCs), which are a result of human activities, being released into the atmosphere, contributing to the depletion of the ozone layer. (2) Human Health: The decrease in air quality leads to several respiratory problems including asthma and lung cancer. Chest pain, congestion, throat inflammation, cardiovascular disease and respiratory disease are some of the diseases that can be caused by air pollution. Water pollution occurs due to the contamination of water and may pose skin-related problems including skin irritations and rashes. Similarly, solid waste or hazardous waste cause severe impacts on the living environments of animal species and humans.

1.3.2. *Water pollution*

In living activities, production and discharge create many different groups of pollutants. These substances can be collected and treated according to the regulations of each region and each country. However, the discharge of untreated waste into the environment is widespread, causing water pollution. Water contamination is caused by marine dumping, industrial waste, sewage (mainly from households) nuclear waste, oil pollution and underground storage leaks. Water pollution is also caused by natural factors such as water flowing through contaminated sites, which draws dissolved compounds into the water (iron, arsenic and some others).

Contaminated water is indicated by an increase in the concentration of inorganic and organic compounds in the water that exceeds the natural system's ability to self-treat. Water pollution primarily affects the living organisms in water and other groups of organisms that are related to the aquatic environment, including humans. The ecosystem in the water environment is altered and reduces the self-cleaning function of the field environment. Water pollution can cause eutrophication, making ecological imbalances more serious.

Water pollution affects human activity, causing infectious diseases (E. coli, Salmonella), skin diseases, intestinal diseases and parasites and neurological diseases (Hg, Cr, As). The reduction of the quality and quantity of water used for production and consumption is also a major problem which is taking place in the world, especially in developing countries.

1.3.3. Soil pollution

Soil pollution occurs when the toxic chemicals, pollutants or contaminants in the soil are in high enough concentrations to be a risk to plants, wildlife, humans and, of course, the soil itself.

The main cause of soil pollution is the overuse of chemicals such as pesticides and fertilizers. These chemicals affect the activity of microorganisms in the soil environment, killing beneficial organisms, reducing soil fertility. In addition, environmental pollution of the soil can be caused by the leakage of radioactive compounds, waste tanks, water permeability through polluted soil, leakage from landfills, industrial waste disposal to the land environment, open toilets and underground burial sites which are near a river.

Soil pollution can have a number of harmful effects on ecosystems and human, plant and animal health. The harmful effects of soil pollution may come from direct contact with polluted soil or from contact with other resources such as water or food which has been grown on or come in direct contact with the polluted soil.

1.3.4. Biological pollution

Biological pollution comes from the invasion by and development of alien species in a certain space. Biological pollution affects the development of native species, causing serious ecological imbalance. Invasive species often adapt quickly and thrive under extreme conditions of the environment.

Biological pollutants can cause a decrease in the productivity of indigenous groups of organisms or the disappearance of a living organism in the short term.

Control of bio-pollution is still facing many difficulties, especially in the case of encroachment. At present, major biological pollution control is still preventive and minimizing, such as flushing the boat and cleaning the wheel before entering the regional or national boundary.

1.4. Environmental quality management

1.4.1. Air quality management: technical tools and data management

Pollutants released from various sources are present and mixed in the giant reactor of the atmosphere where multiple complex chemical and physical interactions occur. Pollutants can be directly emitted from the emission sources such as dust particles (primary pollutants) or formed in the atmosphere through chemical reactions such as sulfate and nitrate particles (secondary particulate matter) or ozone. WHO (2014) reported that globally, in 2012, around 7 million people died as a result of exposure to household (indoor) and ambient (outdoor) air pollution. Regionally, low- and middle-income countries in the Western Pacific and South East Asian regions bear most of the burden, with over 5 million deaths due to exposure to both household and ambient air pollution. Air pollution is now considered as the world's largest single environmental health risk, and clean air is certainly a pressing need for sustainable development.

Air quality management (AQM) is the organized efforts to regulate the extent, duration and location of pollutant emissions to achieve ambient air quality standards, thereby minimizing the aesthetic, environmental and health risks. AQM is a dynamic process that can be illustrated as a cycle of inter-related elements to continuously improve air quality (see Figure 1.6), which comprises of the technical tools and policy actions. The technical tools of the AQM system include (1) air quality monitoring, (2) air pollution emission inventories and (3) air quality modeling. These tools generate and handle large air pollution databases which help us to understand the complex relationships between the source air pollution emissions and the multiple effects on human health, ecosystem and climate. The information provided by these technical tools can help to formulate policies to reduce the pollution emissions, thereby to (1) reduce ambient air pollutant concentrations to acceptable levels, (2) avoid adverse effects to human health and/or welfare and (3) avoid deleterious effects on animal and/or plant life and materials. The integrated AQM could also provide co-benefits in the reduction of climate radiative forcing through co-control measures of air pollution and greenhouse gases, as well as through the reduction of short-lived climate pollutants such as black carbon and tropospheric ozone (UNEP and WMO 2011).

Air pollution monitoring involves measurements of air quality by using traditional equipment (sampling and subsequent analysis) or using more advanced methods for in-situ monitoring with the aid of remote sensing (satellite) or on-line sensor systems. The monitoring results are used to compare against the ambient air quality standards (AAQs) to assess the compliance. The monitoring equipment gives air pollution levels at a location during the measurement period; hence, a

network is required to cover multiple sites to provide information on the status of air pollution in a geographical area. Monitoring should also be done over a long period to provide the pollution trend. The monitoring activity thus generates a large dataset: for example, in a small city with five monitoring stations, each measures six criteria pollutants (CO, PM2.5, PM10, O₃, NO₂, SO₂) on an hourly basis; then, every year, a huge amount of data points are generated, which need good data management strategies for handling and processing.

Emission inventory (EI) is a systematic effort to obtain systematic information on the amount and types of air pollutants and greenhouse gases from emission sources in a geographic area during a specific period of time (USEPA 2007). EI is one of the fundamental components of the AQM process. EI provides input data for air quality model applications which helps to understand the roles of local and long-range transport pollutions in the ambient air quality in a city or a region. The information on spatial distributions of the emissions is useful for siting in air quality monitoring design. The EI database for modeling purposes should include the temporal (normally hourly) emissions of every interested species on every grid (normally 1x1 km for urban scale modeling) of the domain (a few hundred km in size); hence, it is a large dataset to be handled and analyzed. A much larger emission input dataset is required for regional or global scale air quality modeling.

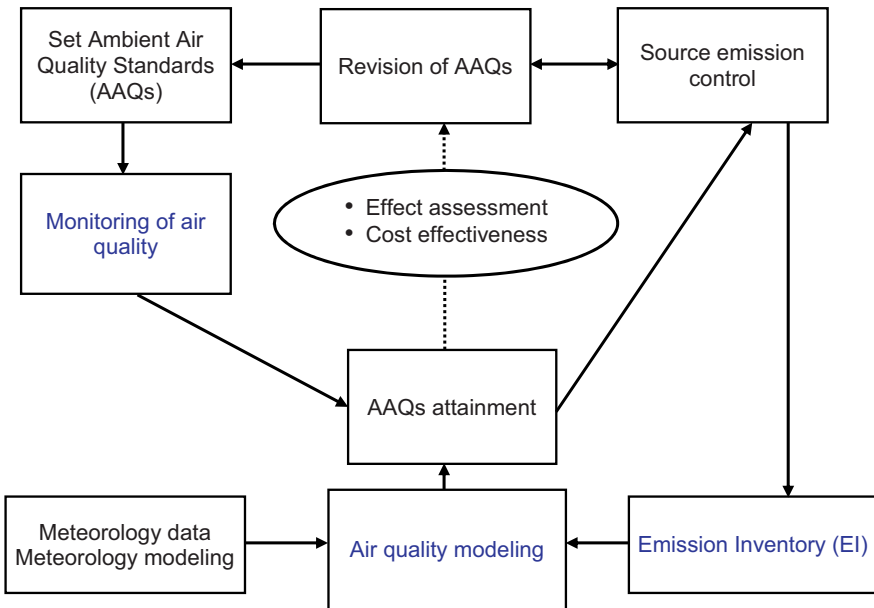


Figure 1.6. Air quality management framework (adapted from Kim Oanh and Polprasert 2014). For a color version of this figure, see www.iste.co.uk/laffly/torus3.zip

Air quality dispersion models use a system of mathematical equations to provide the causal links between emission and ambient concentrations of pollutants. These equations describe the processes of pollutant diffusion/transport, transformation and deposition in relation to meteorology. This is an important tool for AQM which, together with EI and monitoring, provides information to develop and analyze AQM strategies. In particular, air quality modeling provides information on the causal link between emission (current, future scenarios) and ambient concentrations and the potential effects. Such information is required for the policy-making process in formulating and analyzing emission reduction strategies.

1.4.2. Water quality management

Water quality management is an essential action to control and monitor the water resources for human consumption and release. Plans can be conducted to ensure the water resources for industrial, agricultural and domestic activities are available. They include contingency plans, source water protection, the treatment process, the distribution system and continuous monitoring.

Executing the plans requires agreement from stakeholders. Plans for water management depend on both national and international sectors. Plans strictly follow the national strategy for reducing poverty, economic development and balancing the benefit of stakeholders.



Figure 1.7. Framework for water quality (Huang 2007)

1.4.3. Biosphere reservation and management

1.4.3.1. Forest in biosphere

Biosphere is the stratum of the Earth's surface, covering a few kilometres, distance into the atmosphere to the furthest depths of the ocean (Ellatifi 2018). The biosphere is well known as a complex ecosystem composed of living organisms and the abiotic bodies that take energy and nutrients. Forests are the largest, and rich in ecosystems of the biosphere. Types of forest are classified differently depending on their species and environments. Using seasonality and latitudes, the forests are divided into three main different groups in the biosphere: tropical rainforests, boreal forests and temperate forests, including Mediterranean forests.

Recently, deforestation has gained attention and global interest since human activities significantly affect forest area reduction in the biosphere (Figure 1.8), particularly in Africa, Asia and South America. FAO (2016) also reported that the forest-covering area decreased worldwide between 1990–2010, while the agricultural area is increasing (Figure 1.9).

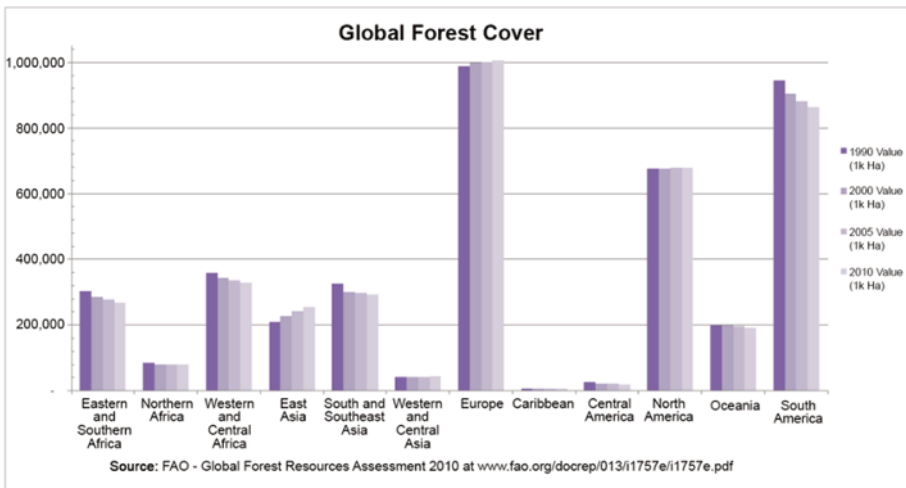


Figure 1.8. The global change of forest cover area during 1990–2010. Source: FAO (2016). For a color version of this figure, see www.iste.co.uk/laffly/torus3.zip

Share of land area used for agriculture

The share of land area used for agriculture, measured as a percentage of total land area. Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures.

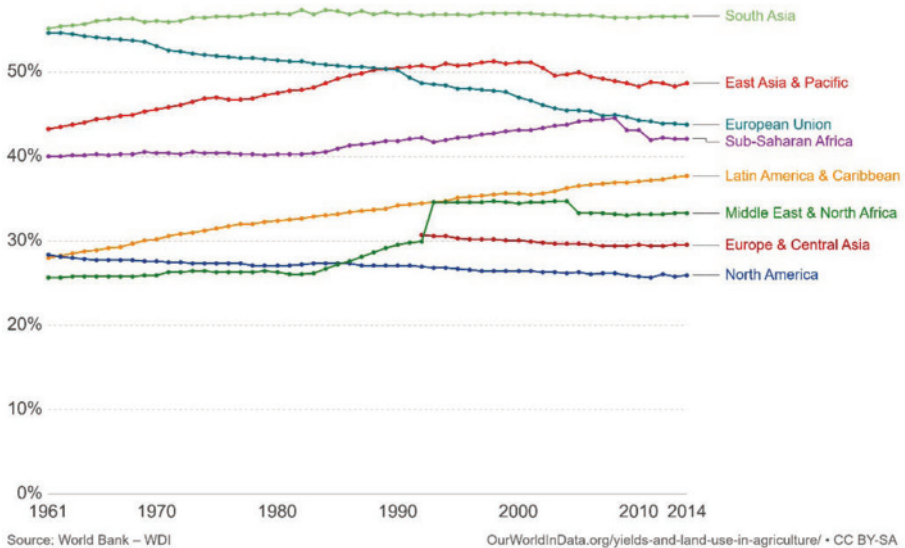


Figure 1.9. The global area used for agriculture 1960–2014. Source: FAO (2016).
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1.4.3.2. Humans and biosphere reservation

1.4.3.2.1. Land use change

The factors that often affect the forest area reduction are rapid deforestation from land development for agriculture and residential areas, forest fires, etc. Since 1990, the South East Asia countries the Philippines, Thailand and Vietnam faced rapid deforestation. The forest transformation data, deforestation and reforestation, showing a lower remaining forest area ($30 \pm 8\%$) of those three countries were lower than the other five countries where forest loss continues to decrease ($68 \pm 6\%$, Cambodia, Indonesia, Laos, Malaysia and Myanmar) (Imai *et al.* 2018). The economic is also the important driving force to the forest transformation (FT). Lai *et al.* (2016) reported the increase in greenhouse gas emissions from land use changes and relations with the economic development between 1990 and 2010. Land use change declined in grasslands (-6.85%) and increased largely in urban areas ($+43.73\%$), farmlands ($+0.84$) and forests ($+0.67\%$).

1.4.3.2.2. Deforestation and reforestation

Deforestation and forest degradation in tropical forests are responsible for 7–14% of anthropogenic carbon emissions (Harris *et al.* 2012) and pose one of the greatest threats to global biodiversity. Therefore, reducing tropical deforestation and even reversing the trend to achieve net forest gain are top priorities of global environmental policy. Harris *et al.* (2012) applied satellite observations to collect gross forest cover loss and produce a map of forest carbon stocks, to estimate gross carbon emissions across tropical regions between 2000 and 2005 as 0.81 pentagram of carbon per year, with a 90% prediction interval of 0.57–1.22 pentagrams of carbon per year.

1.4.3.2.3. Forest fires

Biomass of a tree refers to the weight or mass of its living plant tissue and is generally expressed in the units of metric tons (t) (Walker *et al.* 2011). Biomass can be divided into two main parts: live biomass can be separated into aboveground (i.e. leaves, branches and stems) and belowground (roots). The common method to estimate the aboveground live dry biomass (AGB) of a tree is the weight of the living aboveground plant after the removal of the water content. Typically, the living tree contains water content of approximately 50% of the wet weight biomass. Forests are growing and absorb carbon dioxide from the atmosphere throughout the photosynthesis process. The carbon is stored in the biomass of their stems, branches, leaves and roots, while they release oxygen back to the atmosphere.

The methodology for the measurement and examination of aboveground biomass is variable: (a) a standard method using an allometric equation for the estimation of the tree or plot biomass (Brown 1997), (b) dry weight biomass measurement of harvested trees and (c) satellite image processing.

1.5. Data services for the environment

Any environmental data management planning process or system needs to include substantial coordination and agreement among the relevant federal agencies and international partners in order to ensure proper data stewardship. Different agencies have different missions with respect to collecting, archiving and providing access to different types of data, and these missions sometimes overlap or leave gaps in responsibility for critical data sets; for instance, the transition from research to operations has been a longstanding challenge.

Ground data and satellite data can be used for environmental services. Ground data include parameters from monitoring stations. Satellite data cover map, GIS and RS data. The combination of ground and satellite data generates plenty of tools for

environmental management. The development of technologies for collecting ground and satellite data motivates us to optimize the tools for environmental management toward sustainable development and resource management.

1.6. References

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