15 Ecophysiological Effects of Changing Atmospheric CO₂ Concentration

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15.1 Introduction

The earth’s atmosphere and biosphere evolved together over time, the one affecting the other, such that the composition of the atmosphere was strongly influenced by the exchange of gases among them, lithosphere, and hydrosphere. Green plants, through photosynthesis and respiration, have had significant influence on the carbon dioxide, oxygen, and water budgets of the atmosphere.

The primordial earth contained carbon in the igneous rocks estimated at $1.2 \times 10^{18}$ metric tons ($10^3$ kg) of carbon. From 1% to 5% of this carbon was released to the atmosphere as CO₂, CO, and COS by venting through fumaroles, hot springs, and various volcanisms. Much of the volatile carbon released to the atmosphere has been dissolved in the oceans and precipitated in sedimentary limestone. Dynamic tectonic activity of the earth’s crust has produced a recycling
of some of this carbon in the form of CO\textsubscript{2} to the atmosphere. Li (1972) suggests that 95\% of the volatiles, including H\textsubscript{2}O, CO\textsubscript{2}, CO and H\textsubscript{2}S which were contained in the primordial rocks were released during the first billion years of the earth’s history. Periods of unusual volcanic activity may have released substantial amounts of CO\textsubscript{2} causing impulsive build-up of this gas in the atmosphere until equilibrium could be reestablished with the oceans and sediments.

The carbon cycle of the earth according to our current understanding suggests that a near equilibrium existed among sources and sinks for carbon involving the atmosphere, soils, vegetation, animals, oceans, and sediments prior to the industrial age in about 1860. Since that time there has been a rapidly increasing amount of CO\textsubscript{2} in the atmosphere, released from storage reservoirs by the propensity of mankind for burning fossil fuels (oil, gas, and coal), cutting of forests, plowing of soils, and manufacturing of cement from limestone.

### 15.2 The Atmospheric Heat Balance

Carbon dioxide gas in the atmosphere, along with water vapor, plays a critical role in the thermal balance of the earth. These two minor constituents of the atmosphere are transparent to sunlight but have strong infrared absorption bands, beyond the wavelength range of solar energy, which cause these gases to exchange infrared radiation with the ground surface. If the atmosphere were completely transparent, the longwave radiation emitted by the earth’s surface would flow unimpeded to space and the surface would equilibrate at -20°C instead of +15°C. By absorbing some of the outward streaming, infrared radiation water vapor and carbon dioxide warm the atmosphere. In turn these gases reradiate this energy both to space and toward the ground surface, thereby raising the temperature of the ground and lower atmosphere. Mankind, by increasing the atmospheric CO\textsubscript{2} concentration, is enhancing the radiative exchange between the atmosphere and the ground surface, thereby potentially producing a change of the earth’s climate. Since photosynthetic productivity responds to both the atmospheric concentration of CO\textsubscript{2} and the climate, one may expect substantial changes in all ecosystems, both the managed and unmanaged, as a result.

### 15.3 The Global Carbon Cycle

Carbon is continually exchanged between the biota, oceans, and atmosphere, and each represents a large carbon reservoir. Our knowledge concerning the global carbon cycle is not complete and our estimates of reservoir amounts and fluxes between parts of the system are poor. Figure 15.1 shows the amounts of carbon estimated to be in the atmospheric, terrestrial, oceanic, and fossil fuel reservoirs and the fluxes between them. The carbonate or limestone rocks of the world retain an enormous reservoir of carbon, about $30 \times 10^{15}$ t, and