Full-length paper

The Planet Earth, Life, and Agriculture – Science, Mythology, and History

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Abstract

The planet Earth has three major components: the solid mass, the water bodies, and the atmosphere. While the solid mass and water bodies have oxygen as the dominant element, the predominant element in the atmosphere is non-reactive nitrogen (gas). The reactive nitrogen, ammonia, nitrate, nitrous oxide, and other NO gases make up about 1% of total nitrogen in the atmosphere. The entire life on the planet Earth (both jar – rooted, i.e., plants and ajar – moving, i.e., animals including humans) has evolved and is dependent for its survival on this reactive nitrogen. The non-reactive nitrogen has, however, the major role in preventing the life on Earth from being destroyed by oxidation.

Animal life on the planet Earth has evolved in or near water bodies and has gone through a number of transformations from fish to the present human form. "One life form (smaller) is the food for the other (larger) form" is the rule of nature. And so man also hunted for animals and birds for his food. However, as men settled in communities in tiny villages for their safety and the food that could be hunted in their neighborhood became short in supply, they had to go to far-off places for a kill, leaving their women and children behind. It is these women who started selection and domestication of food producing plants. This was the beginning of agriculture. Later, men also joined them in practicing agriculture and developed farm machinery, such as, sickle, plow, horse hoe, seed drill, tractor and combine, etc. As of today, agriculture is the only way to produce food and the urban centered society of this world must give due respect to the people who practice this noble profession.

The planet Earth

The planet Earth is a part of the 'Solar system', which was born about 4.6 billion years ago. The planet Earth is made up of four layers, namely, the inner core, the outer core, the mantle, and the crust (Oxford University Press, 2009). Crust is the layer on which we live. It has two major physical components, namely, solid mass and water bodies. Earth is enveloped by gases, which form the earth's atmosphere. The earth's atmosphere is made up of nitrogen (N) (78.09%), oxygen (20.95%), argon (0.93%), carbon dioxide (CO_2) (0.038%), and small amounts of other gases. Thus the major component of atmosphere is nitrogen gas (N_2). On the contrary, the major component of water (H_2O) is oxygen, since hydrogen has very little mass and volume as compared to oxygen. The uppermost layer of earth's crust known as soil, which supports all life, has also oxygen as the dominant component – silicates that make up the bulk of the soil, oxides, hydroxides, carbonates, sulfates, etc. are all oxygen compounds. In fact oxygen makes up about 89.84% of the soil on volume basis. The other elements such as silicon, aluminium, magnesium, iron, manganese, etc. fill in the voids between a pile of oxygen depending upon their ionic radii and coordination number (Prasad and Power, 1997). A brief description of components of earth's crust follows.

Water

Water is essential for plant as well as animal (including humans) life. Plants absorb a major part of all nutrients essential for their life through water. Plants and animals (including humans) need water for all physiological processes for their survival and for controlling their body temperature. This would explain, why there is only limited life in deserts, while areas receiving adequate or excess rain and oceans are full of life.

Earth's crust

Earth's crust consists of a large variety of minerals and its surface known as soil is also full of a wide variety of macro and microorganisms. Earth's crust provides anchor to the growing plants and surface for making dwellings of humans and other buildings. Plants take up some of the elements (essential plant nutrients – N, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, boron, molybdenum, chlorine, nickel) for their growth and development from the soil while humans and animals consume plants and their products for their growth and development.

Atmosphere

As already pointed out, the earth's atmosphere contains a number of gases. Nitrogen is present in the largest amount and helps conserve life by preventing oxidation, which is a destructive process. Although the French chemist Lavoisier had given the name l'Azote (without life) to N, it plays a key role in the creation and sustenance of life. Truly speaking N as a component of all proteins is the physical form of life. All processes of life are carried out through enzymes, which are proteins.

However, bulk of N in the atmosphere is present as non-reactive N, and barring a few N-fixing bacteria (*Rhizobium, Azotobacter, Azospirillum,* etc.), plants as well as humans and animals cannot use it for their body building and survival. Reactive N forms (ammonia, nitrates, amides, etc.) make up 1% of the total N present in the universe (Mathews and Hammond, 1999), but are the only source of N for plants and animals including humans. Plants obtain their N from soil as ammonium or nitrates, which are produced by the decomposition of plant or animal residues or added as chemical fertilizer to soil. Some nitrates are formed in the atmosphere by the oxidation of N in the air due to electrical discharges in lightning and are brought down by rain. Humans obtain N for making of their body tissue proteins from plants directly or indirectly from animals feeding on plants. That is why pulses, which are rich in proteins, are so important in the diet of Indians, majority of whom are vegetarians.

Nitrogen. As a chemical, element N has an atomic number of 7 and has 7 electrons (Rao, 1999). Two of these electrons are present in the shell number one and do not participate in chemical reactions. Of the remaining 5, 2 are present in 's' sub-shell, while 3 are present in sub-shell 'p' of shell number 2. These 5 electrons participate in the chemical reactions. All atoms try to complete their octet (2 electrons in sub-shell 's' and 6 in the sub-shell 'p'). Thus an atom of N can either take or share all its 3 electrons in the sub-shell 'p' with another atom, such as in NH_3 (negative valence) or give away or share 1 to 5 electrons with another atom, such as, in N_2O, NO, NO_2, and NO_3) (positive valence). Thus it has a valence variability from −3 to +5. It is probably for this quality that nature has chosen N as the key element in life. These reactive N forms are important for life and its survival. Of the oxides of N, nitrates are important from the viewpoint of fertilizers.

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Nitrate pollution of groundwater and surface water leads to the blue baby syndrome in infants and is considered as responsible for several human and animal diseases (Prasad, 1998). Nitrous oxide (N_2O) is a greenhouse gas and has a greenhouse warming potential of about 273 times that of CO_2. More serious is the fact that it has a life span of about 170 years (Pathak *et al.,* 2009). Nitrous oxide is also responsible for the depletion of ozone layer in the atmosphere. Globally we add about 170 to 180 million tons of reactive N to agricultural systems every year and more than half of it is lost to the environment (Balasubramanian, 2010).

Oxygen. As a chemical element oxygen has an atomic number of 8. It has 4 active electrons in the sub-shell 'p' of the second shell. To complete its octet (2 of the sub-shell 's' and 6 of the sub-shell 'p' of the second shell of an atom of oxygen), it accepts or shares 2 electrons from another element, such as in H_2O, CaO, MgO, etc. (negative valence). Oxygen is important for respiration in plants and animals, which is important for generating energy. Contrary to N, oxygen is an element of destruction. In cremation of a human body, its carbon and other elements are converted to their oxides, for example, CO_2.

Humans are very much dependent upon the atmospheric pressure and associated partial pressure of oxygen (pO_2), since inhaling of oxygen is essential for life. The pO_2 in the lungs is generally lower than the pO_2 in the ambient atmosphere, due to water vapor which gets added to the air breathed in. At sea level the atmospheric pressure is 760 torr (mm of mercury) and the pO_2

in the lungs is about 149 torr (De Sapio, 1978). The atmospheric pressure as well as pO_2 declines with the increase in altitude. The highest altitude at which human life can survive is about 5500 m above mean sea level (amsl), at which the atmospheric pressure is 345 torr and pO_2 is about 81 torr. At Mount Everest, which is 8848 m amsl, the atmospheric pressure is about 250 torr and pO_2 is only 54 torr and a person needs an assured supply of stored oxygen, which he has to carry. In addition to pO_2, the other problem of high altitudes and low atmospheric pressure is the increase in the volume of gases trapped in the intestine, since volume of a gas is inversely related to pressure. At 5500 m amsl the volume of the gases trapped in the intestine is 2.1 times of that at sea level, while at Mount Everest it is 3 times of that at sea level. This increase in the volume of the gases trapped in the intestine creates discomfort. For this reason the cabins of the aeroplanes, which generally fly at 9000 to 13500 m amsl, need to be pressurised.

Carbon dioxide. Another important gas in the earth's atmosphere is CO_2. It is the C in the CO_2 that is fixed as sugars (later transformed to proteins, fats, etc.) in plants through the process of photosynthesis, the only process responsible for the production of food for the animals including humans on the planet Earth.

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As an element, carbon has an atomic number of 6, with 4 of its electrons in the second shell available for chemical reactions. It can either accept or share its 4 electrons to complete its octet, as in CH_4 or give away or share its 4 electrons with other atoms, as in CO_2. Thus so far as valence is concerned it is a fairly balanced element. No wonder it is the core element in all living beings (plants, animals, and humans). Carbon, hydrogen, N, and oxygen are the four basic elements of life. Carbon has a +2 valence also as in CO (carbon monoxide), which is highly fatal to humans.

Carbon dioxide is the end product of combustion or burning of all living matter, while methane (CH_4) is produced under anaerobic conditions such as rice fields.

Carbon dioxide is also liberated after the oxidation of fossil fuels in automobiles and tractors and its increasing concentration in the atmosphere is responsible for global warming, a major issue in environmental pollution. Other major greenhouse gases are CH_4 and N_2O.

Life

Although the origin of life on planet Earth is a mystery, the three components of the earth's planet, namely, earth, water, and air

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and the radiation from Sun played a major role in its evolution. India's ancient literature mentions five elements (components) that created life including humans. These are given in the couplet below:

"*Surya* (sun), *dhara* (earth), *jal* (water), *gagan* (sky, which has been generally taken as void or vacuum, unknowingly referred to nitrogen), *sameera* (wind, specially oxygen),
Panch (five) *tatava* (elements) *se bana sharira* (make up the body)."

Our ancient saints differentiated between N and oxygen, the two dominant gases that make up the earth's atmosphere.

It is generally accepted that life began in water and the cyanobacteria (bacteria having chlorophyll) were the first to split water using the energy from the sun. The oxygen liberated went to the atmosphere, while the hydrogen was used along with carbon from the CO_2 to synthesize sugar (which was later converted to other compounds, such as starch, cellulose, fats, etc.). This process is known as photosynthesis and is responsible for all food produced on the planet Earth for all its animals including humans. Photosynthesis is also solely responsible for the production of oxygen for the earth's atmosphere, which as discussed earlier is most near the earth's surface and declines as one moves upwards.

Probably the first large size animal life was fish, which could survive on the little oxygen dissolved in water. No wonder fish is considered the first of the ten avatars of Lord Vishnu (*Matsya* avatar) (*Garuda Purana* 1.86.10-11). As the life forms learned to live away from the water and survive on the earth's surface, the second avatar of Lord Vishnu was *Koorma* (tortoise), and the third was *Barah* (pig), the first animal form that could live entirely on earth. As the life forms further evolved, the fourth avatar of Lord Vishnu was *Narasingh* (half lion, half man). The first human form evolved was dwarf *Vamana* avatar, which was followed by the full human forms, namely, the avatars, Parashuram, Rama, Krishna, and Gautam Buddha. The tenth avatar Kalki is yet to be born. Thus in Hindu mythology the ten avatars of Lord Vishnu actually tend to describe the evolution of life on the planet Earth. Lord Krishna told Arjuna: "*Yadah yadah glani bhavat Bharat* ..." (Whenever righteousness wanes and unrighteousness increases I send myself forth for the protection of the good and for the destruction of the evil and for the establishment of the righteousness. I come into being age after age) (Gita: 4.7-8; http://en.wikipedia.org/wiki/Avatar). For those who question the animal forms of avatars, it may be pointed out that God was there before the earth and life on earth was created, and will remain even after its destruction. It is also true that God created man and man created God. Man has created God in his own image as Rama and Krishna. Similarly a fish will think God

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in its own image and so forth. Thus God has been there in all life forms. According to another Hindu philosophy, God has no form per se (*Nirakar*) and can adopt any form. Thus Hindu spiritual philosophy is wide open and is in line with the scientific approach to evolution of life on the planet Earth.

Once life is created, it needs food for its survival. This need for food has led to the evolution of agriculture.

Evolution of agriculture

"One life form is the food for the other life form (*Jeevai jeev aahar*)" is the rule of nature. Some simple food chains are: small fish–large fish–crocodile; rat–cat–dog; insects–birds–snakes/big birds/animals. There are hundreds of food chains in nature. When man first emerged on the planet Earth, he also hunted for animals and birds for food. Man is also reported to be a cannibal (McKie, 2009). For their safety humans learned to live in groups in tiny villages. However, as food in the neighborhood got exhausted, men had to go far away for the kill and many a times were away from the family for long periods. In such periods, women had to arrange food for themselves and children by gathering edible leaves, fruits, and grains. Some of them were keen observers and saw plants growing from a single seed and producing large amounts of grain. They also observed that different plants grew during different periods and produced grains at different times. They started collecting grain, stored them, and used them as seed at an appropriate time. They were thus responsible for selection of edible grains, their off-season storage as seed and determining optimum seeding and harvesting time. Thus women were the first agriculturists. Men later joined them and developed suitable tools for land cultivation.

Russian biographer Vavilov (1949–50) suggested that agriculture evolved in several regions of the world at the same or different times. He identified eight geo-centers (geographical locations of the wild ancestors of modern cultivated plants). These along with crop plants domesticated and the likely period during which domestication took place are given in Table 1. Southeast Asia was the earliest such center (9000–1700 BC), followed by Southwest Asia (7500–1700 BC) and China and Japan (6000–5000 BC). Of the cereals, rice was domesticated in the mountain regions of Northeast India and Southwest China (Swaminathan, 1984),

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Table 1. Geo-centers of the world.[1]

Geo-center (Period)	Regions/countries	Crops domesticated
Southeast Asia (9000–1700 BC)	India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Thailand Cambodia, Vietnam, Philippines	Rice, sugarcane, legumes, coconut, bamboo, taro, yam, cucumber, mango
Southwest Asia (7500–1700 BC)	Asia minor, Turkey, Iraq, Iran, Israel, Jordan, Syria, Lebanon, Cyprus, Crete, Greece, Arabian peninsula, Egypt, Afghanistan	Wheat, barley, lentil, chickpea, broad beans, flax, melons, vegetables
China-Japan (6000–5000 BC)	China, Japan	Soybean, sorghum, millet, maize, barley, groundnut, cotton, tobacco, tea, several fruits and vegetables
Central Asia (4000–3000 BC)	Tajikistan, Kazakhstan, Kyrgyzstan, Turkmenistan	Pea, flax, carrot, garlic, radish, spinach, alfalfa, almond, walnut, pistachio, grapes
Mediterranean (by 4000 BC)	Iberian peninsula, Coastal areas of Spain, France, Italy, Albania, Bosnia, Serbia, Croatia, Crete, Cyprus, Coastal Africa	Flax, olive, vines, rutabaga, lupines, oak, lavender
Africa (by 5000 BC)	Nile valley and other parts of Africa	Wheat, cotton, oats, flax, African rice, castor, cowpea, coffee, oil-palm, kola nut
South America (7000–3000 BC)	Peru, Brazil, Bolivia, Ecuador, Argentina, Chile	Manioc, arrowroot, potato, water nuts, sweet pumpkin, tomato, lima bean
Central America (7000–3000 BC)	Mexico, Guatemala, Costa Rica, Honduras, Nicaragua, Panama, El Salvador	Maize, cacao, tomato, potato, kidney bean, pumpkin, sunflower, red pepper, tobacco, avocado

1. Source: Vavilov (1949–50).

while barley and wheat were domesticated in the valley of Euphrates and Tigris (De Candolle, 1959). As regards rice, it is mentioned as '*dhana*' in Yajurveda (IV.24.7) written about 3700–2000 BC) (Nene, 2005). Several vegetable and fruit crops, such as, onion, garlic, and grapes were domesticated in Central Asia.

According to Bender (1975) also, Southeast Asia was the ideal hearth for the evolution of agriculture because it had the ideal conditions for transition from hunting-gathering to farming. Bountiful food and flourishing trade and economy were also responsible for the development of religions like Buddhism in India, which later spread to entire Asia.

As per the western literature (Braidwood, 1960), agriculture emerged in the Neolithic or Stone Age between 7500 and 6500 BC in West Asian hilly regions embracing Israel, Jordan, Iraq, the Caspian basin, and Iran. The oldest Neolithic settlement sites, known as Ali Kosh and Bus Mordel were in Iran (7500 BC), Jerico in Jordan (7000 BC), and Belt Cave below Caspian in northern Iraq (Randhawa, 1980). The earliest farmers known as Natufians (named after a site in Jordan) used sickles of small flint blades set with gum into grooves/shafts of bones. These sickles were used for cutting grass and crop stalks. Animals such as goat, sheep, pig, and cattle were also domesticated in this region. Natufians had also developed pottery, basket making, and spinning of flax and wool.

In the Chalcolithic or Bronze Age (3000–1700 BC), bronze equipments were introduced in agriculture. The Chalcolithic revolution occurred in Mesopotamia (the valley of Tigris and Euphrates rivers in Iraq) and from there it spread to Egypt and later to Indus Valley. The people who settled in Mesopotamia were known as Sumerians. They invented plow, bullock carts, and sailing boats and developed irrigation. They also worked out an accurate solar calendar. The nomadic shifting gradually gave way to the cereal–fallow system. Forage crops of lucerne and berseem (Egyptian clover), flax, beans, and chickpea were introduced later in farming. Gradually the tiny villages of the Neolithic age changed to towns and cities and foreign trade of agricultural products was developed. According to Whyte (1960), salinity caused by 1000 to 1500 years of irrigated agriculture was the main cause of the decline of Sumerians.

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The home of Aryans is believed to be Southern Russia. They left their homeland about 1800 to 1600 BC, perhaps due to drought and famine, and dispersed east and westwards. One group conquered northern Iran, the other Asia minor and the third entered the Indian subcontinent through Afghanistan and Baluchistan. Sanskrit, Greek, Latin, and Zen are sister languages derived from a common ancestral language spoken by Aryans in their homeland (Randhawa, 1980). Aryans domesticated horse in the region now occupied by Ukraine, Kazakhstan, and Turkmenistan. Horse chariots were faster than bullock carts and helped in transporting agricultural produce from villages to urban centers.

(Editors' note: Aryan migration to India is considered a myth by most Indologists today.)

In India, the Aryans settled in an area now known as Punjab. They cut forests and built their villages. They grew wheat, barley, pearl millet, rice, and linseed. They grazed their cattle and milk was an important part of their diet, which continues even today in Punjab. Their major contribution was the development of the art of smelting iron, which was used for making plowshare, which permitted deeper cultivation of soil. Iron was also used for making sword and other war weapons. Vedas were composed by Indo-Aryans during 1500 to 1200 BC (c. 8000–1000 BC – Editors) and were handed over from father to son. The deities invoked for good crops and betterment were *Agni* (fire), *Surya* (Sun), *Marut* (wind), *Prithvi* (earth), *Varun*, and *Indra*.

The farm revolution leading to modern agriculture began in England in 18^{th} century (Prasad, 2004). Jethro Tull (1647–1741 AD) invented a horse-drawn hoe and a seed drill that permitted better seeding. Robert Black Well (1725–1795 AD) bred horses for draft, cattle for beef and milk, and sheep for wool and mutton. Lawes and Gilbert started the manufacture of superphosphate in 1847 AD. The money raised from the sale of superphosphate was donated for the establishment of now world famous Rothamsted Experimental Station in England. This was followed by the development of a process for commercial production of ammonia (a major fertilizer per se and a major source of other N fertilizers such as ammonium sulfate, ammonium nitrate, and urea) (Prasad, 1998) by the German chemist Fritz Haber, who received the Nobel Prize in Chemistry for this discovery in 1918. He, however, used osmium as a catalyst for this reaction, which was too expensive. Another German chemist Carl Bosch later showed that iron oxides could be used as a catalyst in this process. This made commercial production of ammonia a reality. Bosch also received Nobel Prize in Chemistry in 1930.

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A large number of Europeans moved to North America (now USA and Canada) for a better life and carried their agricultural practices with them. The American farmers had big farms and needed many helping hands with horse hoe husbandry. Some of the labor employed on these farms was brought in from African countries. To overcome this problem the tractor was developed in USA in 1910, which revolutionized the agriculture not only in USA but also in the entire world. The United States became the major country for producing food grains and meat, which was exported to Europe.

However, over cultivation of land led to Dust Bowl in the Great Plains of America and conservation tillage practices were developed to prevent wind erosion (McCalla and Army, 1961). These conservation practices involved seeding crops in fields covered with crop stubbles and other residues left from the previous crop (Prasad and Power, 1991; Prasad, 2010). Zero-till seeding of wheat after rice is now being widely practiced in the rice-wheat cropping belt of the Indian subcontinent (Ladha *et al.,* 2009).

As regards new and high-yielding crop cultivars, development of hybrid maize (corn) during 1905–20 was the first major breakthrough (Reeves, 1944). Hybrid maize cultivation also led to the development of fertilizer industry in USA, since it needed high rates of fertilizer application. This phenomenon has also happened in India. Introduction of high-yielding non-lodging dwarf wheat brought in the Green Revolution in India (Swaminathan, 2006) and increased fertilizer use several fold. Similarly, the development of rice hybrids in China has increased rice production (Virmani, 1996) and fertilizer consumption in that country. Application of molecular genetic techniques and development of genetically modified (GM) crops has added to the hope of producing more and more of quality agricultural products with less use of agricultural chemicals/pesticides. The most successful case is that of Bt cotton (Singh and Kaushik, 2007). Other newly developed GM crop varieties include beta-carotene and iron rich 'Golden rice' (http:/www. golden rice/org/content5-GCGH/GCGHI. hotmail) and vitamin rich orange flesh sweet potato (http:/www.biocassava.org/program description.htm). Efforts are also underway to develop zinc and iron fortified maize, wheat, etc. (http://www.harvestplus.org/ contents/target-countries and crops).

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Development of water harvesting techniques is another major development in agriculture (Pali *et al.,* 2007). In India, the per capita availability of water has declined from 5177 m^3 in 1961 to 1869 m^3 in 2001 and it is likely to decline to 1341 m^3 in 2025 (Ghosh, 2008). Water harvesting techniques are mentioned even in ancient literature on agriculture in India (e.g., in Kashyapiyakrishisukti written c. 800 AD as quoted by Nene, 2009). Agriculture consumes 80% of total water used in India and rice is the crop that consumes most water. Development of aerobic rice varieties in China and Brazil and now in India (Prasad, 2011) will largely help in reducing agricultural water consumption in India and other countries.

Advances in agricultural research from time to time have sustained ever increasing human population on planet Earth and saved it from the pangs of famine, hunger, and malnutrition. Yet strange as it may seem, the urban elite centered society has never showered scientific laurels, such as, Nobel Prize on agricultural scientists, as on scientists from physics, chemistry, medicine, etc. with the single exception of Dr Norman E Borlaug, who was conferred Nobel Prize for peace for the development of high-yielding dwarf varieties of wheat that led to Green Revolution in India and elimination of hunger in the world as a whole. It is hoped that someday the urban

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centered society will realize that agriculture sustains life on the planet Earth and those practicing it deserve due credit, recognition, and respect.

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