What Are the Limits and Extremes of Air, Water and Land Resources? A Review Article

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Abstract: The three fundamental gifts of nature viz., air, water and land are precious resources that sustain man and the planet. When one quantify the cost of these resources used on daily basis, especially air at little or no cost, then we appreciate they are priceless. Take the cost of oxygen that we breathe free of charge, the cost of potable drinking water and the cost of land we have used all of our life, which we often take for granted, then can we understand that they should only have been affordable by super millionaires. Yet, nature has made it possible for everyone in the universe to have all of them at little or no cost. Because, most of them are free, we abuse the privilege and take a freelance attitude towards their protection and conservation. After all, they are public goods. But, any second our rent on land or landed property expires, or our income could not afford a cup of potable water, or we could not afford to pay hospital bill for oxygen administration in the state of coma, then we realise they are private and expensive goods. Virtually all human activities are mediated by air, water and land resources namely: agriculture, industry, infrastructure, exploration, navigation, expedition, science, art, technology, architecture, medicine and military. Let us explore the extremes and limits of these resources from scientists who have spent all their time and resources exploring human resources too numerous to be covered in this episode.

Key words: Air • Water • Land • Precious resources • Public goods • Private goods • Human activities • Extremes and limits

INTRODUCTION

Air is an envelope of gases that define the atmosphere. Apart from the normally ever present variable water vapour, the main components of an unpolluted version of the earth’s atmosphere, according to Baird [1] are diatomic or molecular nitrogen (N\textsubscript{2}) that is about 78% of the molecules, diatomic oxygen (O\textsubscript{2}) that is about 21%, argon that is about 1% and carbon dioxide (CO\textsubscript{2}) that is about 0.04%. These and other gases are wonderful resources. On the other hand, Jackson and Jackson [2] gave the waters of the earth’s surface as constituting the hydrosphere. According to these workers, about 70% of the surface of the globe is covered with liquid water and about 10% of the land is covered by ice. The same authors gave 97% of the mass of the hydrosphere as oceanic and 2% ice, leaving only approximately 1% that is fresh water. In their report these figures remain remarkably constant because water is cycled through the hydrosphere by the processes of evaporation, condensation and runoff.

The Royal Society of Chemistry (RSC) [3] gave the world’s total land mass as 13.07 billion hectares, with 11.3% cultivated for crops, 24.6% under permanent grazing; 34.1% under forest and woodland and about 31% under urban industry and roads. Collins World Atlas [4] defines land as the outermost layer of the earth that is only 0.1% of earth’s total volume. It is made up of continental crust and oceanic crust, which differ from each other in age, as well as in physical and chemical characteristics. According to the authors, the crust together with the uppermost layer of the mantle is also known as the lithosphere and within the lithosphere is the loose material called soil which forms the uppermost layer
of the earth’s surface composed of the inorganic fraction, that is material derived from the weathering of bedrock and the organic fraction derived from the decay of vegetable matter. From RSC [3] standpoint, soil as a resource is vital for the production of food, fibre crops and timber. The essence of this review is to assess the extremes and limits of air, water and land resources. The extremes and limits in this context is defined to mean extraordinary, novel or abnormal characteristics or attributes of the resources, that can signify positive or negative impacts. Positive impacts may also be advantages or disadvantages, just as negative impacts may also be advantages or disadvantages. Their inference in this review will be based on each given scenario. From scientific communities well vexed in this subject matter, there are bound to be diverse opinion on when these resources reached their extremes and limits as they are very difficult parameters to predict. But, based on exploratory findings, the work attempts to differentiate the extremes and limits of these fundamental human resources. It is also geared to invoke more controversial thinking and debate on a wider community.

Air Resources Limits and Extremes

Air as an Envelope of Gas: The atmosphere is an envelope of gases that surrounds the earth, with a boundary between it and space that is not sharp [1, 5, 6, 2, 7]. For Jackson and Jackson [2] virtually the entire atmosphere is within 80,000 km of the earth’s surface and the bulk of it (99% by mass) is found in the lower 50 km. In their records, the primitive atmosphere that enveloped the early earth, prior to the evolution of life, was formed as a result of out-gassing from the interior of the planet. This atmosphere, according to the authors was probably dominated by nitrogen (N), water and carbon dioxide (CO$_2$), citing probably lower concentrations of ammonia (NH$_3$), methane (CH$_4$) and oxygen (O$_2$). It is thought that the atmosphere underwent a dramatic change with the evolution of photosynthetic organisms (basically green plants), which convert CO$_2$ and H$_2$O into carbohydrate and with the aid of light. The green plants release the oxygen into the atmosphere and retain the carbohydrate. The bulk of the carbohydrate, according to most of these workers is later oxidized back to carbon dioxide and water during the process of anaerobic respiration.

Some CO$_2$, according to Jackson and Jackson [2] are buried in sediments and permanently removed from the atmosphere. The net result is a decrease in the CO$_2$ of the atmosphere and an increase in its O$_2$ levels. In addition to these facts, the earth’s current atmosphere is a complex mixture of gases, suspended particles, dominated by two gases i.e., nitrogen and oxygen, which together account for 99% of the volume of dry air. The authors records that composition of the atmosphere is remarkably stable given that it is not isolated from its surroundings. Indeed, it is an open system, being subjected to both matter and energy inputs and outputs.

Air-Matter-Atmosphere-Space Continuum: There is evidence of small and insignificant exchange of matter between the atmosphere and space. Rather, there is a substantial two-way flow of matter between the earth (particularly the oceans and the atmosphere. Most importantly, H$_2$O, N, O and CO$_2$ continually enter and leave the atmosphere as part of their biogeochemical cycles [2]. According to these authors, in the absence of human intervention, the rates of addition of these and other materials to the atmosphere are approximately equalled by their rates of removal, noting that overall composition of the atmosphere has therefore remained essentially constant over recent geological time by virtue of dynamic steady state.

Air Amplified by Human and Natural Activities: Human intervention has been identified as removing steady state condition of several trace gases including carbon dioxide (CO$_2$), carbon monoxide (CO), oxides of nitrogen (NO, N$_2$O, NO$_3$, NO$_2$), chlorofluorocarbons (CFC), oxides of sulphur and methane [5, 2, 7]. In some cases, according to Jackson and Jackson [2], the levels of these gases in the atmosphere are increasing very rapidly. The energy inputs to the atmosphere, according to these workers, arise as a result of irradiation from both the sun and the earth, from convection and conduction of thermal energy from the earth’s surface, known as sensible heat and in the form of latent heat of vaporisation from evaporation and condensation of water. Similarly, the atmosphere losses energy to its surroundings as a result of radiation. Altogether, the processes accounting for layered structure of the current atmosphere.

Air Dynamics from Layered Strata: Before space is the region of atmosphere, approximately at an altitude of 100 km, known as thermosphere which is one of the imaginary layer that has low density and pressure (<0.01 atm). In this region, the atmosphere is predominantly made up
of atoms and ions [2]. They are formed when high energy, short-wavelengths solar radiation (\(\leq 200\) nm) is absorbed. The species produced are reactive and tend to recombine, reforming the reactants and releasing energy. As this energy is principally released in the form of thermal motion of the molecules, atoms or ions, the net effect is warming of the atmosphere. In this regard, according to Jackson and Jackson [2], the temperature of the thermosphere decreases with decreasing altitude until the mesopause is reached at about 90 km. According to authors explanation, the particles in the upper thermosphere absorb the short-wave radiation that is responsible for the warming effect. Conversely, little of this radiation penetrates to the lower thermosphere and as a result, is not warmed to the same extent.

The population of molecular species increases with decreasing altitude. In this layered structure, it is on record [2] that below the mesopause, in the mesosphere and stratosphere, that warming increases with the absorption of solar radiation with wavelengths between 200 and 300 nm. The warming phenomenon reaches a maximum at the stratopause (the boundary between the mesosphere and the stratosphere). Below this altitude, the population of molecules continues to rise but the amount of the radiation in the 200 to 300 nm region decreases as it has been removed by molecules at higher levels. As a result, the temperature of the stratosphere decreases with decreasing altitude.

**Air Magnified by Ozone:** In Jackson and Jackson [2], Baird [1]; Briggs [5] ozone received some scientific details. According to Jackson and Jackson [2], irrespective of ozone being generated in large amounts within the atmosphere (35,000,000 kg per day), the concentration within any one region of the atmosphere remains remarkably constant. This, according to the authors lies on the rates of production matching nearly with removal. In more explanatory version, the workers note the trace levels of this gas at all altitudes below the stratopause, reaching a maximum concentration of about 8 – 100 ppm within the stratosphere. This stratospheric band of relatively concentrated ozone is what is contemporarily referred to as the ozone layer, although, according to the workers, it is clearly a misnomer given the low absolute concentration of the gas. Jackson and Jackson [2] caution that ozone is not major constituent of any part of the atmosphere. Indeed, according to them, if all of the ozone within the atmosphere were concentrated at sea level, it would produce a layer only about 3 mm thick. Despite its relatively low abundance, the workers affirm the extraordinary importance of ozone. It absorbs harmful ultraviolet light principally in the region of 200 – 320 nm. It does this by virtue of the photochemical reaction. It is akin to molecular oxygen that absorbs harmful ultraviolet radiation, but in a different region, near 200 nm.

Human activities are also implicated in eroding the ozone layer, while ozone at the stratospheric level help in filtering sunrays; the ozone at ground level is not welcome and is considered to be a pollutant [1, 2, 3].

**Air in Greenhouse Effect and Liveable Planet:** This is one of the extremes of air resources, because beneath the stratosphere is the troposphere which contains about 90% of the mass of the atmosphere and majority of the trace gases [2]. The reaction into which these trace gases enter, according to these authors are highly complex and of considerable importance. Among them is being key to many of the processes that produce hydroxyl and nitrate radicals. Within the troposphere, absorption of terrestrial radiation causes warming near the surface of the earth. This is called greenhouse effect. Without this effect, the mean temperature at the surface of the earth would fall from its current value of 15°C to -17°C or lower, probably making the world uninhabitable [2].

To better appreciate these extremes of air resources, the earth radiates infrared electromagnetic spectrum, with only molecules in vibration states; and with different dipole moments being able to absorb this radiation. In Johnson and Johnson [2] (2000) account, some major components of the dry air namely: nitrogen, oxygen and argon do not have this characteristics and are therefore incapable of absorbing terrestrial radiation; consequently they are not greenhouse gases. In contrast, water vapour and many of the trace gases, including carbon dioxide and methane, are greenhouse gases as they are capable of absorbing the infrared rays. They are implicated not only in making the plane earth habitable, but also in controversial global warming.

Interestingly, the presence of greenhouse gases does not cause warming in all situations [2]. This explains the workers, is due to their ability to absorb and emit infrared radiation at the same time. For example, when the density of greenhouse gases is sufficiently low, radiation emitted by one molecule is unlikely to be absorbed by a neighbour and may escape into space. This can occur in the upper atmosphere, cooling it down. Conversely, in
regions of the atmosphere where there is a high density of greenhouse gases, the absorption process dominates and a net warming occurs. For this reason, the greenhouse effect is most pronounced in the lower parts of the troposphere. Hence, within this region, temperature increases with decreasing altitude. This has two important consequences. Firstly, there is a temperature minimum at the tropopause. This acts as a cold-trap, condensing out many of the less volatile components of the troposphere, greatly inhibiting their transfer into the stratosphere. For example, very little water crosses the troposphere and consequently the stratosphere is relatively dry. What is more, much of the water that it does contain is produced within the stratosphere as a result of the oxidation of volatile hydrogen-containing species such as methane. Secondly, the warming of the lower parts of the troposphere causes it to expand, decreasing its density and causing it to rise. This produces turbulence and relatively rapid mixing. In contrast, the stratosphere, according to Jackson and Jackson [2] is calm. This is because a temperature inversion exists within this zone, that is, warmer air lies over cooler, denser air.

Air in Agricultural and Environmental Health: The mean residence time of CO$_2$ in the atmosphere is relatively small (3.2 years) as reported by Jackson and Jackson [2]. This is close to the time taken for the lower atmosphere to mix. The perturbations in the outward or inward flux of atmospheric CO$_2$, according to the authors alter the size of the reservoir, local variations and residence time in the atmosphere, which are also extremes of air resources.

Nitrogen (N) is essential to life. It is a fundamental component of amino acids. They are building blocks of proteins which are both natural catalysts called enzymes and chemical messengers within an organisms known as hormones. They are also known for the transportation and storage of small molecules such as oxygen. To buttress their extremity, it is an essential component of the bases that make up DNA. This is the molecule that carries the genetic code of the living creatures. Nitrogen has other biologically significant roles. For instance, there are organisms that are capable of utilizing them in its oxidized forms as a substitute for oxygen during respiration while there are others that can oxidize reduced nitrogen with oxygen to liberate energy. In fact, according to Jackson and Jackson [2], nitrogen has many biologically available oxidation states. This means that biologically mediated redox reactions are central to nitrogen cycle. The alterations in chemical speciation that such reaction brings about often result in the movement of nitrogen from one reservoir to another in a different physical location.

Many workers have attempted to understand the processes involved in the nitrogen cycle. This is particularly true of those processes that relate to crop growth. This is because nitrogen is frequently the limiting factor in crop yields. Despite the large amount of work made in this field, Jackson and Jackson [2] laments on several unanswered questions. One of them is the magnitude of many of these fluxes in the cycle which the authors likened to more of intelligent guesses. For the workers, nitrogen is not a major component of either the crust or the oceans, but 76% of the mass of the atmosphere is molecular nitrogen (N$_2$). Hence, according to their arguments, this atmospheric gas is the most single reservoir in the nitrogen cycle. But the question, may arise. Why all the limitations in its availability. The workers give a clue. The process in which atmospheric nitrogen is reduced to ammonia and subsequently incorporated into amino acids is called nitrogen fixation. This process is carried out by limited number of prokaryotic microorganisms and leguminous plants, that may be free living or in symbiotic association with plants. The energy for nitrogen fixation is supplied by the oxidation of carbohydrates.

Invariably, microbial fixed nitrogen becomes available to terrestrial higher plants by a number of pathways. The higher plants from symbiotic relationships with nitrogen fixers are supplied with amino acids directly by the microorganisms concerned. Some higher plants obtain their nitrogen from soil solution in an inorganic form. This is either ammonium or nitrate. The process by which this inorganic nitrogen is transformed into amino acids is called assimilation, while the biological processes by which reduced inorganic nitrogen are oxidised in the soil to nitrate is known as nitrification. In the absence of human intervention, this process is largely responsible for the presence of nitrate in the soil solution. Nitrification is mediated by the activity of nitrifying micro-organisms, that derive their energy from the oxidation of fixed nitrogen in the form of ammonia, or ammonium to nitrite; and then to nitrate. The principal organisms involved in this process belong to the genus Nitrosomonas and Nitrobacter. Thus, during nitrification, small amounts of the gas – nitrous oxide may be liberated as a consequence of incomplete oxidation of ammonium to nitrite [2].
Similarly, the nitrogen in living terrestrial organisms is returned to the soil via excretion and death. The nitrogen held within the decaying matter represents the major store of fixed nitrogen in the soil. This is broken down by organisms called saprophytes that live on dead organic matter and is ultimately released as ammonia or ammonium. This process is called ammonification or mineralisation. The ammonium produced is either returned to the atmosphere, temporarily held as ammonium within the cation exchange capacity of the soil, taken up by plants, or subjected to nitrification. Unfortunately, not all the nitrified nitrogen is taken up by plants. Some of the crustal nitrate is leached from the soil by percolating waters and is ultimately washed to the ocean. In addition, nitrified nitrogen is returned to the atmosphere from the land and the oceans via the reduction of nitrate to nitrogen and/or nitrous oxide. These are all reasons why nitrogen is always a limiting nutrient in crop production. We can see the leakages based on this account by Jackson and Jackson [2].

Soil systems represent an important sub-cycle within the larger nitrogen cycle. The process of assimilation, ammonification and nitrification facilitate circulation within this sub-cycle, while the processes of fixation, leaching and denitrification represent inputs and outputs from and to the larger nitrogen cycle. There are non-biological routes by which atmospheric nitrogen may become available for use by organisms. At high temperatures, nitrogen oxides can be formed by the direct reaction of nitrogen with oxygen. This happens naturally in lightning and artificially during the burning of fuels in air. A significant proportion of the oxides, according to Jackson and Jackson [2] are converted into nitrates. These are readily removed from the atmosphere by rain as they are highly soluble. On entering the soil or surface waters, these nitrates become available for uptake by plants. Terrestrial plants growth is frequently limited by the supply of nitrogen, irrespective of the large quantity fixed by natural processes. This has necessitated the use of nitrogenous fertilizers by farmers to substantially increase crop yields. The bulk of these fertilizers are made by the Haber process, developed by Haber and Bosch during 1910-1914. This has played a major role in the maintenance of adequate food supplies [2]. For these workers, the world’s food supply has kept pace with demand; based on exponential growth in human population that have been sustained so far. This assertion and optimism of these workers is subject to controversy from 2000-2015 (barely 15 years) as supported by Igboji [8, 9, 10] – Agriculture in Peril and others; as well as Pretty [11] – Agriculture: Reconnecting land, people and nature. There are many equations to agriculture that is not only dependent on nutrient nitrogen and world population. As at the time of Jackson and Jackson publications in 2000; the world population was already near to 6 billion, with a target of over 10 billion by 2050 [11] and populations outstripping food production, availability and affordability [8, 9, 10].

**Water Resources Limits and Extremes**

**The Universal Water Equation:** These are essential in the understanding of the extremes and limits of water resources. The cycling of water between land, sea and air impacts across agriculture, environment, society and the economy [12]. For these workers, the characteristics of many terrestrial ecosystems, for example, are heavily influenced by water availability and in the case of in-stream ecosystem and wetlands, by the quantity and quality of water in rivers and aquifers.

Water is fundamental to human life and many activities – mostly agriculture, but also industry, power generation, transportation and waste management. The availability of clean water often is a constraint on economic development. Consequently, there have been scientific studies on the potential of hydrology, focusing on cycling of water and water resources; as well as on human and environmental use of water. Key areas reported by Arnell and Liu [12] are on changes in water balance, changes in stream flow through the year, reliability of water supply reservoir and risk of flooding.

The waters of earth surface constitute the hydrosphere [1]. The worker accounts 70% of surface of globe covered with liquid water and 10% with ice. In hydrospheric allocation, 97% is oceanic, 2% ice and 1% fresh water [1]. The circle of water is via evaporation, condensation and runoff. Water has high melting and boiling points (approximately <0°C and 100°C); high enthalpies of melting and vaporisation, high specific heat capacity and low thermal conductivity. It is less dense as a solid than liquid; excellent solvent, especially ionic compounds that contain single charged ions and organic compounds that contain nitrogen or oxygen atom. River and sea water have high levels of total dissolved solids, sodium chloride, particles and atmospheric gases. When rainwater hits the ground and percolates through the rock its composition changes. Its total dissolved solids also increases, proportion of its individual dissolved constituents alter. River water tends to be
markedly more concentrated than rainwater and have Ca\(^{2+}\), rather than Na\(^+\) as its dominant cations [1]. Water in rivers with catchment area is highly weathered and tends to be significantly different from rainwater.

Fresh water lakes total dissolved solids are largely determined by the river that flows into them. While lakes are calm, rivers are not. Their behaviour to a great extent is governed by the fact that pure water has density maximum at 4°C [1]. The aquifer is the major source of potable water and is less than 2% of entire global water source. Changing land use and land management practices, like use of agrochemicals has been reported to alter hydrological system, often leading to deterioration in the resource baseline [12]. The workers reported changing demands to be putting pressure on available water resources. On the other hand, the workers reports that per capita demand is falling in some countries (subject to debate). Similarly, according to the authors, many objectives and procedures of water management are changing. In many countries, there is an ever increasing move towards sustainable water management and increasing concern for the needs of the water environment. Falkenmark [13] recorded the Dublin statement, agreed at the International conference on water and the environment in 1992, which urged the sustainable use of water resources, aimed at ensuring that neither the quantity nor the quality of available resources are degraded. The concern according to the author is to ensure that key water resources at any given time and over several decades (to me centuries) relate to accessible safe drinking water, water for growing food (to me this refers to water from natural precipitation and sources of water for total or/and supplemental irrigation); overexploitation of water resources (to me this includes water resources abuse like pollution, dumping of toxic wastes at sea, wasting water and over harvesting of both marine and fresh water, biotic and abiotic resources); consequent environmental degradation and deterioration in water quality. The list is endless, but the passion by Falkenmark [13] extends the magnitude and significance of the stresses within and between countries. The World Meteorological Organisation [14] highlighted comprehensive assessment of freshwater resources of the world under the mandate of UN Commission on Sustainable Development; while Cosgrove and Rijbersman [15] published the task given to World Commission for Water resources by the World Water Council to produce a vision for a water secure world. This led to series of periodical reports on global water issues as emphasized by Gleick [16].

The State of Knowledge on Hydrology and Water Resources: Some work on hydrology and water resources [17, 18, 19] reported changes in hydrology by various means namely: defining scenarios for changes in inputs to hydrological model based on output of general circulation models (GCMs); constructing scenarios that are suitable for hydrological impact assessments, developing and using realistic hydrological models, understanding the linkages in hydrologic systems).

Scientists have documented the considerable effort on the following: developing improved hydrological models for estimating the environmental parameters on hydrological changes, improved models to simulate water quantity and quality with focus on realistic representation of the physical processes involved, developing models of general applicability, with no locally calibrated parameters and increase use of remotely sensed data as input [20, 12, 21]. According to these workers, even though different hydrological models can give different values of stream flow for a given input, the greatest uncertainties are in estimating groundwater recharge, water quality or flooding and other additional uncertainty. The actual impacts on water resources such as water supply, power generation, navigation, depend not only on the estimated hydrological change but also on changes in demand for the resource and assumed responses of water resources managers. Imagine a world of over 6 billion people and land area of over 13 billion hectares that need potable water and possible total or supplemental irrigation for sustainable agriculture.

Scientists have made considerable advances in the understanding of relationships between hydrological processes at the land surfaces and processes within the atmosphere above. These advances have come about largely through major field measurements and modelling projects in different geographical environments, coordinated research programmes such as those sponsored by International Geosphere-Biosphere Programme and large scale coupled hydrology modelling projects [12]. Other studies have explored linkages between El-Nino and North Atlantic Oscillation and hydrological behaviour, in an attempt to explain variation in hydrological characteristics over time. These studies in North America [22, 23, 24, 25]; South America [26, 27]; Australasia [28]; Europe [29] and Southern Africa [30] have emphasised variability not just from year to year, but also from decade to decade, although patterns of variability vary considerably from region to region. Most studies for several decades ago recorded reconstructed longer records based on proxy data sources [31, 32].
Such research has been extremely valuable as it helps in interpretation of observed hydrological changes over time (with particular attribution to environmental changes) and provides a context for assessment of future changes and opens up possibilities for seasonal flow prediction [24]. It also emphasise that the hydrological baseline cannot be assumed to be constant.

The management of water resources Water management has been based on minimisation of risk and adaptation to changing circumstances, usually taking forms of altered demands [33, 34]. A wide range of techniques have been developed and applied in this sector for many years. One widely used classification between increasing capacity e.g. building reservoirs or structural flood defences, changing operating rules for existing structures and systems; changing operating rules for existing structures and systems; managing demand and changing institutional practices. The first two often termed “supply-side” strategies, whereas the later two are termed “demand-side”. Over past years, there has been a considerable increase in demand-side techniques. International agencies such as World Bank [34] and initiatives such as the Global Water Partnership have been promoting new ways of managing and pricing water resources in order to manage resources more effectively [33]. These are innovative and worth keeping up in view of the limitations of potable water in the world.

There is also documented evidence of water managers in some countries who have taken into consideration arrangements for long term water resources planning. For example, in the UK [35] water supply companies being required by regulators to consider investing for future resources. This provision dates back to 1997. In the US, Arnell and Liu [12] included American Water Works Association who normally urges agencies to explore the vulnerability of their system to changes. These authors were also conscious of the variations in the ability of water management agencies to alter management practices in all countries of the world.

The Assessment of Water Resources

From Precipitation Perspectives: Precipitation has been reported as the main driver of variability in the water balance over space and time and changes in precipitation have very important implications for hydrology and water resources. Hydrological variability over time in catchments is known to influence variations in precipitation over day, season, year and decades. Flood frequency is affected by changes in the year to year variability in precipitation and changes in the short term rainfall properties such as storm rainfall intensity. The frequency of low or drought flows is affected primarily by changes in the seasonal distribution of precipitation, year to year variability and the occurrence of prolonged droughts [12].

There are different trends in different parts of the world, with general increase in Northern Hemisphere mid and high latitudes, particularly in autumn and winter and a decrease in the tropics and subtropics in both hemispheres. There is evidence of frequency of extreme rainfall in the US [36] and in the UK [37]. In both countries, a greater proportion of precipitation is falling in large events than in earlier decades [37]. Changes in seasonal precipitation are evenly variable and depend on changes in the climatology of a region. In general, the largest percentage precipitation changes over land are found in high latitudes, some equatorial regions and Southeast Asia, although there are large differences between climate models. Potential changes in intense rainfall frequency have been difficult to estimate from global climate models, largely due to what Hennessy et al. [38] called coarse spatial resolution. Similarly, the workers and McGuffie et al. [39] observed that the frequency of heavy rainfall events is generally likely to increase with environmental changes. Increasing temperatures mean that a smaller proportion of precipitation may fall as snow, while areas where snowfall are currently marginal may see seizure of snow fall, with consequent, but very significant implications for hydrological regimes [12].

From Evaporation Perspectives: Evaporation from the land surface includes evaporation from open water, soil, shallow groundwater and water stored on vegetation, along with transpiration through plants [12]. According to these workers, the rate of evaporation from the land surface is driven essentially by meteorology controls, mediated by the characteristics of vegetation and soils and constrained by the amount of water available. The primary meteorological controls on evaporation from a well watered, often known as potential evaporation are the amount of energy available, net radiation, moisture content of the air (humidity) – a function of water vapour content and air temperature and the rate of movement of air across the surface, a function of wind speed. Increasing temperature generally results in an increase in potential evaporation, largely because the water holding capacity of air is increased. Changes in other meteorological controls according to these workers often worsen or offset the rise in temperature; and there are possibilities that increased water vapour content and
lower net-radiation lead to lower evaporation demands. The relative importance of different meteorological controls, for example, potential evaporation is driven by energy and is not constrained by atmospheric moisture contents, so changes in humidity are relatively not important [12]. Furthermore, the authors observed that atmospheric moisture content is a major limitation to evaporation, as changes in humidity have very large effect on the rate of evaporation.

Similarly, Friend et al. [40] and Arnell and Liu [12] gave vegetation cover, type and properties to play very important role in evaporation. According to these authors, interception of precipitation is very much influenced by vegetation type (as indexed by the canopy storage capacity) and different vegetation types have different rates of transpiration. Moreover, different vegetation types produce different amounts of turbulence above the canopy, the greater the turbulence, the greater the evaporation. A change in catchments vegetation, directly or indirectly as a result of environmental changes affect the catchments water balance. There are also hydrological literatures on the effects of changing catchments vegetation. Friend et al. [40] reported changes in biome type under environmental conditions, while Arnell and Liu [12] reminded the scientific community that such hydrological changes and indeed changes in agricultural land use have not been fully explained.

In addition, the authors include transpiration from plants through their stomata as driven by energy, atmospheric moisture and turbulence since plants exert a degree of control over transpiration, particularly when water is limiting. Again, stomatal conductance in many plants, according to the workers falls as the vapour pressure deficit close to the leaf increases, followed by temperature rises and less water availability to the roots. This leads to fall in transpiration. Superimposed on this short-term variation in stomatal conductance is the effect of atmospheric CO₂ concentrations. Increased CO₂ concentrations reduce stomatal conductance in C₃ plants, which include virtually all woody plants and temperate grasses and crops; although Arnell and Liu [12] affirms that results of experiment show the effects vary considerably between species and depend on nutrient and water status. The actual rate of evaporation is constrained by water availability. A reduction in summer soil water, for example, normally leads to a reduction in the rate of evaporation from catchments despite an increase in evaporative demands. To this, Arnell et al. [17] estimated a sample of UK catchments, noting that the rate of actual evaporation would increase by a smaller percentage than the atmospheric demand for evaporation, with greater difference in the driest catchments where water limitations are greatest.

From Groundwater Recharge Perspectives: Groundwater is the major source of water across much of the world, particularly in rural areas in arid and semi-arid regions, but there has been very little research on the potential effects of environmental changes [12]. Aquifers generally are replenished by effective rainfall, rivers and lakes. This water may reach the aquifer rapidly, through macro pores or fissures, or more slowly by infiltrating through soils and permeable rocks overlying the aquifer. A change in the amount of effective rainfall alters recharge and duration of recharge season. Increased winter rainfall for mid-latitudes, according to the workers result in increased groundwater recharge. Higher evaporation makes soil deficits persist, offsetting an increase in total effective rainfall. Various aquifers recharge differently. The main types according to the workers are: unconfined and confined aquifers. An unconfined aquifer is recharged directly by local rainfall, rivers and lakes and the rate of recharge are influenced by the permeability of overlying rocks and soils. Shallow unconfined aquifers along floodplains are most common in semi-arid and arid environments are recharged by seasonal streamflows and depleted directly by evaporation. Changes in recharge are determined by changes in the duration of flow of these streams, which locally increase or decrease the permeability of the overlying beds. In semi-arid areas of Kenya, Arnell and Liu [12] reported flood aquifers improvement by construction of subsurface weirs across river valleys, that form subsurface dams from which water is tapped by shallow wells. Thick layer of sands substantially reduces the impact of evaporation. According to Mailu [41, 42] those wells become perennial water supply sources even during prolonged droughts.

Salinger et al. [43] reported groundwater in low lying islands as being sensitive to change. For example, in the atolls of the Pacific Ocean, water supply is recorded to be sensitive to precipitation patterns and changes in storms tracks by the worker. For Amadore et al. [44], a reduction in precipitation coupled with rise in sea level cause diminution of the harvestable volume of water and reduces the size of the narrow freshwater lense. In Arnell and Liu [12], many small Island States, including some Caribbean Islands, record seawater intrusion into freshwater aquifers; as a result of over pumping of
aquifers; with unconfined aquifers sensitive to local abstraction and seawater intrusion. Similarly, the quantification of recharge is complicated by the characteristics of the aquifers themselves, as well as overlying rocks and soils [12]. The scientists links a confined aquifer to overlying bed that is impermeable, which local rainfall does not influence. It is normally recharged from lakes, rivers and rainfall that occur at distances ranging from a few kilometres to thousands of kilometres. Recharge rates also vary from a few days to decades. The workers also reports Bahariya Oasis and other groundwater aquifers in the Egyptian Desert to be dependent on recharge at the Nubian Sandstone outcrops in Sudan and hence are not seriously affected by seasonal or inter-annual rainfall or temperature of the local area. The rate of recharge was calculated by using carbon-14 isotopes ($^{14}$C) and other model techniques. This has been possible for aquifers recharged from short distances and after short durations. Again, the workers observed that recharge takes place from long distances and after decades or centuries has been problematic to calculate with accuracy. The workers also lament on the poorly known and very heterogeneous medium through which recharge takes place.

From Lakes Endowment Perspectives: Lakes, in Arnell and Liu [12] report are particularly vulnerable to changes in environmental parameters. According to these scientists, variations in air temperature, precipitation and other meteorological components directly cause changes in evaporation, water balance, lake level, ice events, hydrochemical and hydrological regimes and the entire lake ecosystem. There are many different types of lakes, according to these workers, classified according to lake formation, the amount of water exchange and hydrochemistry. Closed lakes are drained by out flowing rivers. Endorheic lakes are very dependent on the balance of inflows and evaporation and are very sensitive to change in either environmental intervention. The largest endorheic lakes in the world are the Caspian and Aral Seas, lake Balkash, Lake Chad, Lake Titicaca and Great Salt Lake. Some of the largest East African Lakes, including Lakes Tanganyika and Malawi, are also regarded as endorheic. The Aral Sea has been significantly reduced by increased abstractions of irrigation water upstream; while the Great Lake in the US has increased in size as a result of increased precipitation in its catchments, while that of Qinghai in China has shrunk following a fall in catchments precipitation. Many endorheic lake systems include significant internal thresholds, beyond which change may be very different. For example, Lake Balkash, as reported by Arnell and Liu [12] consists of a saline part and a fresh part, connected by a narrow strait. Several rivers discharge into the fresh part, preventing salinization of the entire lake. Based on their report, it follows that a reduction in freshwater inflows, automatically change the lake regime and lead to salinization of freshwater. This effectively destroy major source of water for a large area.

Exorheic lakes, on the other part, according to these scientists are sensitive to changes in the amount of inflow and the volume of evaporation. Their report shows that Lake Victoria (East Africa) levels increased for several years following a short duration increase in precipitation and inflows. There are significant thresholds involving rapid shifts from open to closed lake conditions; while progressive southward expansion of Lake Winnipeg under postglacial isostatic tilting was suppressed by a warm dry condition in the mid-Holocene, when the north basin of the lake became closed (endorheic) and the south basin was dry [45]. A progressive moister climates within past 5, 000 years, as documented by Arnell and Liu [12] caused a return from closed to open (overflowing) lake conditions in the north basin and rapid flooding of the
south basin about 1,000 years later. Other examples include Lake Manitoba, which was dry during the warm Mid-Holocene [46]. Computation of sustainable lake area under equilibrium water balance after [47] indicate that a return to dry conditions compared to Mid-Holocene; caused the 24,000 km² lake draining a vast area from the Rocky Mountain East almost to Lake Superior; to become endorheic again [45].

**From Quality Perspectives:** Water in rivers, aquifers and lakes naturally contains many dissolved materials, depending on atmospheric inputs, geological conditions and climate. These materials define the water’s chemical characteristics. Its biological characteristics are defined by the flora and fauna within the water body and temperature, sediment load and colour are important physical characteristics. Water quality is a function of chemical, physical and biological characteristics, but is a value-laden term because it implies quality in relation to some standard [12]. Based on their scientific evidence, different uses of water have different standards. Defining pollution as deterioration of some aspect of the chemical, physical or biological characteristics of water (its quality) to such an extent that it impacts some use of that water or ecosystems within the water. Major water pollutants include organic material, which cause excessive growth of algal in lakes and coastal areas, known as eutrophication (leading to algal blooms, which may be toxic and consume large amounts of oxygen when decaying); and toxic heavy metals and organic compounds. The severity of water pollution is governed by the intensity of pollutants and the assimilation capacity of receiving water bodies, which depends on the physical, chemical and biological characteristics of stream flow – but not all pollutants, can be degraded [12].

In these authors’ analysis, chemical river quality is a function of the chemical load applied to the river, water temperature and the volume of flow. The load is determined by catchments geological and land use characteristics, as well as by human activities in the catchments. Again, agriculture, industry and public water use result in the input of polluting substances. Stream water quality is affected by stream flow volumes, which invariably affects both concentration and total loads [12]; while Carmichael et al. [48] showed that higher temperature and lower summer flows in Nitra River, Slovakia produced substantial reductions in dissolved oxygen concentrations. Another research in Finland [49] showed that changes in stream water quality, in terms of eutrophication and nutrient transport are very dependent on changes in stream flow. For a given level of inputs, a reduction in stream flow lead to increases in peak concentrations of certain chemical compounds [50].

The consequences of these direct changes to water quality of polluted water bodies are profound, as summarized by Varis and Somlyody [50] for lakes. Increases in temperature deteriorate water quality in most polluted water bodies; by increasing oxygen-consuming biological activities and decreasing the saturation concentration of dissolved oxygen. On the other hand, dissolved oxygen concentration reduces when air temperature is higher. Water quality in many rivers, lakes and aquifers is heavily dependent on direct and indirect human activities. Land use and agricultural practices have significant effect on water quality and so do management actions to point and non point source pollution; and wastewaters discharged into the environment. In such water bodies, future water quality is dependent on human activities, including water management policies and the direct effect of environmental variables [51].

**From Water Uses Perspectives:** Arnell and Liu [12] account on water resources speak of their dependence on changes in resource base, demand and environment. For these scientists, demand in its economic sense means the willingness to pay for a particular service or commodity and is a function of many variables, particularly, income (for household), output (for industries or agriculture), family composition, education levels). Others, according to the authors, are the usefulness of the demand function based on ability to predict the effects of changes in causal variables; and in measurement of the demanding party’s willingness to pay, as a measure of gross benefits; to the demanding party of various quantities. The quantities actually purchased (the quantities of water withdrawn or used) over time are the result of the interaction of factors affecting demand as defined and conditions of supply (availability). Thus, according to Arnell and Liu [12] the fact that the quantity purchased over time increases could be the result of falling costs of supply (a shift in the supply curve) rather than an increase in demand (shift in demand curve). In this regard, the term “demand” often is used as a synonym for requirements, which reflects usage of the term in large parts of the water sector.

Furthermore, demands are classified along two dimensions: instream or offstream; consumptive or nonconsumptive. Instream demands use water within the
Examples, according to Arnell and Liu [12], include ecosystem uses, navigation, hydropower generation, recreation and use of the water course for water assimilation. Offstream demands extract water from the river channel, lake or aquifer. They include domestic, industrial and agricultural demands, as well as extractions and services, directly or indirectly; it follows that ecosystems provide many of the goods and services simultaneously. For example, agricultural systems provide much of our food, fiber and fuel needs and at the same time influence biogeochemical cycling, soil and water quality and biodiversity. Similarly, many services from ecosystems lie outside market systems, making it difficult to price them [58, 59, 60, 61].

Although, several studies estimating different values for non market services from ecosystem exist [60], they can be applied only with low to medium confidence. Valuation of ecosystem services is complex because many goods and services occur simultaneously. Thus, it is not sufficient to consider, for example, the timber value of the forest. For WRI [57] we must also consider the soil/water protection that trees provide, the habitat for pollinators, or the bequest value of the forest. In their opinions [62, 63, 56, 64, 65] the earth has been subjected to many human-induced and natural changes, often referred to as global change. These changes include pressures from increased demand for resources driven by economic growth, increased human population; land use and land cover change, the accelerated rate of anthropogenic nitrogen production and other air pollutants and urbanization and industrialization.

Land Resources Limits and Extremes
The Ecology of Land Resources: The ecosystem is subject to many pressures: land use change, resource demands and population changes. Landscapes are becoming more fragmented. Ecosystems provide many products and services that are crucial to human survival [55, 56, 57]. Ecosystem affects biogeochemical and physical feedbacks to the biosphere and atmosphere. Hence, are important for the functioning of the earth’s systems. According to UNEP [56] ecosystems form a landscape and are connected in many ways, often by streams, rivers and wildlife. Again, they include landscape fragmentation, along with other human activities which invariably affect ecosystem’s ability to meet human needs. Similarly, UNEP [56] and WRI [57] mention biomass production, biogeochemical cycling, soil and water relationships and animal-plant interactions (including biodiversity) as major functions of ecosystems. Within these functions, various products (goods) and services including food, fiber, fuel and energy, fodder, medicines, clean water, clean air, flood/storm control, pollution, seed dispersal, pest and disease control, soil regeneration, biodiversity, recreation/amenity are very important. Since, society places values on these goods and services, directly or indirectly; it follows that ecosystems provide many of the goods and services simultaneously. For example, agricultural systems provide much of our food, fiber and fuel needs and at the same time influence biogeochemical cycling, soil and water quality and biodiversity. Similarly, many services from ecosystems lie outside market systems, making it difficult to price them [58, 59, 60, 61].

The Biology of Land Resources: The terrestrial biosphere consists of plants, animals and soil biota and their environment. The distribution of biota within and across the ecosystems is constrained by physical and chemical conditions of the atmosphere, the availability of nutrients and/or pollutants and disturbances from natural origin (fire, wind-throw) or human land use. At global scale, the sum of all ecosystems (including the marine biosphere) exerts a significant role on the balance of carbon and water in the atmosphere [2].

The Agriculture of Land Resources: Antle et al. [66] credited agriculture in the 20th century to have accomplished several results. The first, according to these workers is the remarkable increase in food supply at a faster rate than growth in demand, despite rapidly growing populations and per capita income subject to
critics as in Igboji [8, 9, 10] and Pretty [11] as earlier mentioned. Their second assertion relates to key summary indicators of the balance between global demand, supply and world prices for food and feed grains (also very controversial – see Igboji [8, 9, 10] on Agriculture in Peril and others and Pretty [11] on Agriculture: Reconnecting People, Land and Nature. On the other hand, Johnson [67] and Antle et al. [66] showed that during the second half of the 20th century, real inflation adjusted prices of wheat and feed corn declined at an average annual rate of 1-3%. Again, the US Department of Agriculture [68] also asserted food security to have improved globally, leading to a decline in the total number of people without access to adequate food (they may retract this assertion based on 2015 trends of events). As at 1999 the USDA [68] gave impression of declining real price of food grains which has greatly improved the food security of the majority of the world’s poor, who spend a large share of their incomes on these staples (very controversial in 2015, in just 16 years things have changed drastically). The FAO [69] got a better picture by asserting the global number of variations in food security among regions, countries and social groups. Most of these people are vulnerable because of low incomes or lack of access to food. All of these add to limits in land resources that are central to agricultural productivity.

The pressures on agriculture sector always encompass: degradation of natural resources – soils, forests, marine fisheries, air and water. This diminishes agricultural production capacity [70]. Soil degradation is always major challenges for global agriculture. According to these authors, it is induced via erosion, chemical depletion, water saturation and solute accumulation. Furthermore, in the post-World War II, Oldeman et al. [71] approximated 23% of the world’s agricultural land, permanent pastures, forests and woodland to be degraded as defined by the United Nations Environment Programme; while Pretty [11] estimates world degraded land at over 50 million ha and Scherr and Yadav [72] put annual loss of land at 5-10 Mha yr⁻¹. Alexandratos [73] estimates 10-15% of irrigated land as degraded to some extent by waterlogging and salinization. All the authors assert that degradation of natural resources hinder agricultural productivity and dim optimism of satisfying growing world food need at acceptable cost.

**CONCLUSIONS**

Under natural and conventional conditions, it can be said that air resources are unlimited if pollution free (which is not possible); even though pollution in the actual sense may not be used as index of air limitability. But pollution drives a lot of air processes including the quality of the ones we breathe, their effects on ozone layer depletion, global warming, climate change, melting of arctic ice, rise in sea level, tsunami and other environmental catastrophes that shape the extremes and limits of air resources.

On the other hand, fresh water resources are limited, while marine waters are unlimited to the aspect of quantity, but limited on the angle of quality and marine resources harvesting. They are subject of abuse in the controversial practices of dumping at sea and over-harvesting of marine lives. The underground water (aquifer) that supplies only 1-2% of potable water are prone to contamination and pollution by leachates from waste treatment plants and sewage facilities; and in most regions by heavy metals such as cadmium, aluminium, arsenium, lead, zinc. The cost of treating other fresh water like rivers, lakes, ponds, streams, dams and their scarcity (less than 5% of global water resources) also confirms their limitability. Their contamination by dissolved solids including salts, industrial chemicals/wastes/effluents, agricultural/ industrial/ domestic pesticides, clinical and radioactive wastes makes a case for their limitability. Hence, a popular saying “Water! Water! Water! Everywhere but limited potable and affordable one to drink”.

On the next hand, land/soil is a limited resource, even from elementary knowledge of economics; not only on the part that less than 25% of the land surface is made up of land, the rest (over 70%) by water. To add insult to injury, the whole world land has been based on conquer and occupy especially from the era of colonial and military expeditions. How each man came to find himself in any land in the universe is another thesis of its own. The limitability of land/soil from the point of degradation, contamination, pollution is endless. The cost of reclamation of low lying and upland land especially under degradation/ contamination/ pollution namely: earthquake, erosion, landslide, desertification, salinization, flooding, soil spilling, overgrazing, over-tillage and others too numerous to mention are very enormous and adds pressure to land resources. Moreover, agricultural production is more on land (over 95%) and less on water (<5%) and virtually none on air (those on aerobiology) can tell better.

The world land resources are not evenly endowed. While the Asian continent especially China and India are highly endowed, other countries are less endowed. Nevertheless, land endowment is not without its peculiar challenges and hiccups namely: ecological
disasters – earthquake, flood, tsunami which are very calamitous when they strike and cost of resettlement and rebuilding very staggering. In other less land endowed countries there may be problem of land tenure system, common or public goods/services, economic, social, cultural, religious and political instability which makes land more limited or vulnerable. There are countries with less land, but more economic, political and technological wherewithal to produce for the whole world including United States and The State of Israel. Therefore, the question of the extremes and limits of air, water and land resources are very difficult to crack. Nevertheless, the way we misunderstand, misrepresent, undermine, overexplore, overexploit, overignore and underrate these fundamental resources of lives on this planet calls for mathematical turn of mind.

The rate of free air we breathe per second for 100 years of average life span; the water we buy and drink for this same time; the land/soil we occupy at extreme cost for this same time calls for serious thought and investigations by even a baby. All of us are in a hurry. Busy bodies 24 hours for the 100 years average life span. What are we up to? We never break off a second to ask pertinent questions and proffer a likely answer. May be there is a reason. Nothing in the world belongs to anybody or under the control of anybody including the wealth we labour to acquire for the 100 years average life span. Once death strikes, the people nearby will simply say “sorry, he has passed away” and you disappear from history book no matter your fortune, fame, knowledge and wisdom. Hence, everyone lives as if there will be no tomorrow. Until tomorrow, we must understand that our air, water and land resources are limited.

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