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Exploring How Human Activities Disturb the Balance of Biogeochemical Cycles: Evidence from the Carbon, Nitrogen and Hydrologic Cycles

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ABSTRACT

All around us today there is a clear evidence proof suggesting an observable influence by human on biogeochemical cycles which are likely to cause serious consequences for humanity. Activities of human affect the biogeochemical cycles, both directly as well as indirectly. If scholars were able to make clear the degree of how specific human actions are affecting the biogeochemical cycles, they (researchers) would be able to come up with ideas on how to better position toward suggesting strategies aimed at mitigating against disturbances that are worst. This paper aims at exploring how human activities affect the balance of biogeochemical cycles in relation to the Carbon, Nitrogen and Hydrologic Cycles. A literature analysis attempts to use a diversity of search engines such as Scopus, Researchgate, PubMed, Google Scholar, Summon, Hinari, CAB Abstract, OARE Abstract, Academia, Dimension, Mendeley, SSRN search strategy toward retrieving research publications, "grey literature" as well as expert reports from working group. This paper reviews some of the work done on this topic as well as locate the converging results of interest in all the studies as well as proffered solutions toward this menace with the purpose of forestalling future occurrence. Due to the actions of numerous human activities, the characteristics/features of several components of biogeochemical cycles are experiencing changes which are most likely led to long-term changes. It is essential to forecast the magnitude as well as degree of these changes so that the needed ameliorative actions could be originated well in time.

1. Introduction

Entirely organisms tend to amend their milieu, as well as human beings remain no exemption. As the population of human continues to grow as well as technology power continue to increase, the scope as well as the modification nature has transformed drastically. Currently, the term "human- dominated ecosystems" was associated agricultural fields with elicited images, pastures, or urban landscapes; it can now be applied to all the earth with greater or lesser force [1,2]. Directly, humanity dominated several ecosystems, as well as no earth's surface ecosystem is free

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of pervasive human influence [3,4]. Interestingly, we don't just live on the Earth, but we change it. The Earth is a different place because of humans. We have changed the atmosphere, the seas and the surface of the land in many places through the activity of humans that have started to have a remarkable impact on the planet's climate and ecosystems and is characterized by massive global changes, including climate change, biodiversity loss, poverty, as well as food insecurity [5]. The challenge for society is to adapt to and mitigate these changes while transforming our systems, making them more efficient, inclusive, resilient and sustainable, for a better environment, and a better life, leaving no one behind. Thanks to us, some animals are much less common and others much more so. One of the things we have changed is the way that carbon is cycled. If we were to do something fairly common, such as go to the garage, fill our car up with fuel and use it to go for a day out, we have affected the carbon cycle. The fuel that we put in the car was made using oil, a fossil fuel. By using this we have reduced the amount of oil left. Driving the car involved burning the fuel. It used the process of combustion. This added to the amount of carbon dioxide in the atmosphere. In fact, simply by eating and breathing, we have moved carbon around its cycle. We have eaten food (which grew, or which are something that grew). This decreased the number of plants and we breathed out carbon dioxide [6,7]. The carbon cycle existed long before humans did of course, and there have been animals (and plants) respiring for millions of years before humans first walked on the surface of the Earth. In fact, for many years, people didn't affect the movement of carbon much. All that has changed in the last few hundred years. We have used up a huge amount of the available fossil fuels through burning them and this has released large volumes of carbon dioxide into the atmosphere [8]. These fuels have been used to provide transport, generate electricity and power factories to make things [9]. We have also changed the way that we use land. Large areas have been cleared of natural vegetation. The dense growth that has been removed stored much more carbon than the crops planted in their place. Not only have we added to the processes that produce carbon dioxide, but also, we have reduced the ways that it is removed. Looking at the carbon cycle, the way that carbon dioxide is removed from the atmosphere is by photosynthesis. Plants use carbon dioxide in the process of releasing energy from sunlight. If we grow, or allow to grow, fewer plants or smaller plants, their need for carbon dioxide is less.

Interestingly, man has become a powerful force now. He has tremendous power at his command. His actions have a global impact and has altered natural flora and fauna over a large surface area of the world [1-4,8]. Human establishments and agriculture are fast expanding as well as infringing on natural systems. Hill tops levelled, grasslands invaded, forests are cleared, marshes drained and even land under water is reclaimed to provide space for human establishments and his agriculture [1-4]. The soil is bared, natural ecosystems remain destroyed, flora as well as fauna exterminated and are replaced by such artificial systems as agriculture, horticulture, animal farms etc or else a jungle of steel and concrete structures comes up in place of high green vegetation. The two most important consequences of human activity are:

i. Reduction in ecosystem complexity and diversity

Humans remained over simplifying the structural complexities and diversity, which occur in undisturbed natural ecosystems. Agriculture, for example, is just an applied management of trophic chain. The complicated several tiered trophic natural system structures is been reduced to two links viz: Primary producer as well as human. Man sets an artificial agricultural system, protects the biomass [10-16], which develops in his fields from pathogens insects, birds and other herbivores. All this increases the efficiency of production as the energy needed for maintenance of a simple structure is much lower than the complicated ones. However, simple trophic structures are more vulnerable to catastrophic changes. An unforeseen pathogen could reduce or eliminate the single species, which happens to constitute the entire population of producers. In a complicated ecosystem with each trophic level composed of a number of species, several alternatives are available for energy to flow, for materials to circulate in the system, which is thus maintained in operative state [17]. Man, also tends to oversimplify microbial community present in soils or water bodies. Use of chemical fertilizers and intensive agriculture lead to depletion of organic material on which microbial populations depend for nutrition which insecticides washed down into water and the soil kill susceptible organism directly [10-16]. Sewage, wastewater from industries and surface run-offs from agricultural fields pollute the aquatic systems in which susceptible organisms are suppressed [4,18,19]. Our soils not only provide food for the humanity but also regulate the operations of important biogeochemical cycles such as those of nitrogen, sulphur and carbon. Changes in microbial community within the soil on large scale affect its capacity to perform operations of these cycles effectively [17].

The diversity of animal communities is also adversely affected by human activity. Man has taken a few species domesticated and protected them to form huge populations. Those species, which are left out, are finding it

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increasingly difficult to cope up with the stresses imposed by human activity around them. The overall effect of this is the replacement of diverse community with a community consisting of few species only which man chose to domesticate. This has led to a severely damaging effect on grasslands forests and has caused outbreak of animal diseases which have often acquired dimensions of an epidemic. The process of reduction in genetic diversity has also been taking place along with over simplification of natural ecosystems. A number of plants and animals have become extinct or are on verge of extinction. Evolution of new texa and extinction of ill adopted ones have been taking place in a balanced way ever since life came into existence. However, the strain placed by human activity has speeded up the process of elimination of weaker species. This is a sad state of affairs. Each extinct species takes away with it a combination of traits or gene pool, which took millions of years to evolve. The loss is irreparable [4,17]. To date about 150 species of plants are cultivated on large scale. Of these 150 species, only 29% provide the total food stock available to the humanity. Man has slowly and consciously been reducing the number of plants and animals, which he breeds. Selection of varieties for better output, resistance to the environmental conditions, better tastes and flavours etc has led to a drastic reduction in genetic diversity of plants and animals. The varieties or species in which he is no longer interested are vanishing one after the other. The decreased genetic diversity of plants cultivated on large-scale places restrictions on the possibilities of creating new varieties through breeding programs. Growing genetically uniform plants or livestock is their increased vulnerability to unkind environment or unforeseen pathogens.

ii. Changes in biogeochemical cycles

Ruthless exploitation and pollution of the environment has disturbed the operation of all-important biogeochemical cycles. The magnitude of waste materials has been growing persistently. Those waste or their decomposition products are regularly added to the various components of the environment in significant quantities to disturb even the global cycles. Man has been extracting substantial quantities of material which represent biological output of pass ages, at a rate much faster than the rate of their formation. So are the deposits of various minerals elements and metal formed by persistent biogeochemical activity of millions of years, which are being depleted at a very fast rate. These resources belong to our children and grandchildren as much as they do to us [3]. The policy of reckless exploitation of natural resources is one which our future generation will rightly deplore.

2. Global Carbon Cycle

2.1 Main features

The carbon budget of the earth is closely linked to the atmosphere, land and oceans and to the mass movements of air around the planet. The earth contains about 10^{23} g of carbon. All but a small fraction is buried in sedimentary rocks and is not actively involved in the global carbon cycle. The carbon pool involved in the global carbon cycle (Figure 1a, b & c) amounts to an estimated 55 x 10^{18} g or 55, 000 Gt (Gt is a gigaton, equal to 1 billion [10^9] metric tons or 10^{15}g). Fossil fuels, created by the burial of partially decomposed organic matter, account for an estimated 10,000 Gt. The oceans contain the vast majority of the active carbon pool, about 38,000 Gt, mostly as bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^-) [32]. Dead organic matter in the ocean's accounts for 1650 Gt of carbon, and living matter, mostly phytoplankton, 3 Gt.

In addition, the study of nature-based solutions frequently places emphases on the amount of carbon they could take away from the atmosphere. A novel study examines how these solutions adaptation strategies affect global temperatures, an important measure as humanity tries to control global warming. It was suggested that an eco-nature-based strategy may perhaps decrease peak warming through an additional 0.3°C beneath a scenario in agreements with a 2°C general temperature rise come 2085. Cécile Girardin, a climate-change policy analyst as well as seven other contemporaries clarify in what way environmental related projects that is managed, protected as well as restore ecosystems may perhaps offer climate, biodiversity as well as socio-economic benefits, if done correctly, and rapidly. Hence, the terrestrial biosphere contains an estimated 1500 Gt of carbon as dead organic matter and 500 Gt as living matter (biomass). The atmosphere, the major coupling mechanism in the cycling of CO_2, holds about 750 Gt of carbon [21,22]. In the ocean, the surface water acts as the site of main exchange of carbon between atmosphere and ocean. The ability of the surface waters to take up CO_2 is governed largely by the reaction of CO_2 with the carbonate ion to form bicarbonates. In the surface water, carbon circulates physically by means of currents and biologically through assimilation by phytoplankton and movement through the food chain. The next exchange of CO_2 between the oceans and atmosphere due to both physical and biological processes result in a net uptake of 2Gt per year by the oceans, while burial in sediments accounts for a net loss of 0.1 Gt of carbon per year. The uptake of CO_2 from the atmosphere by terrestrial ecosystems is governed by gross production (photosynthesis). Losses are a function of autotrophic

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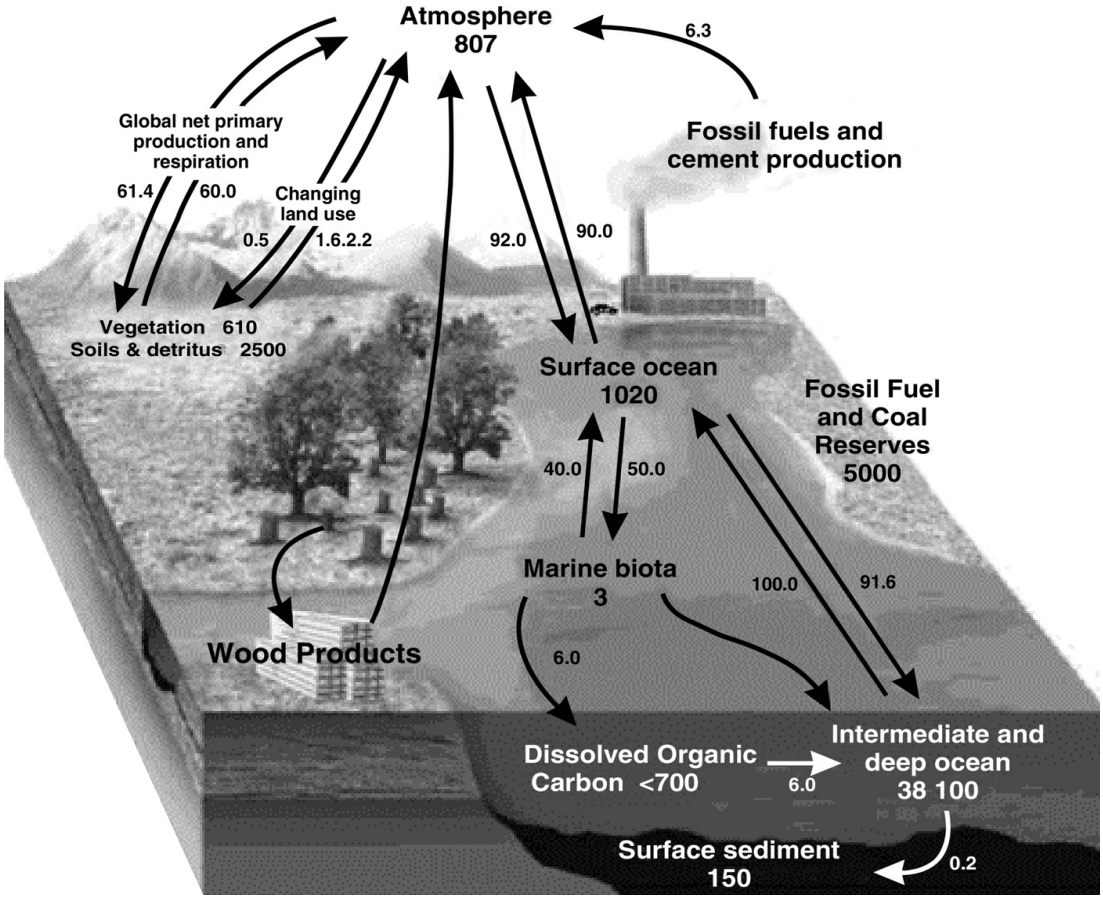
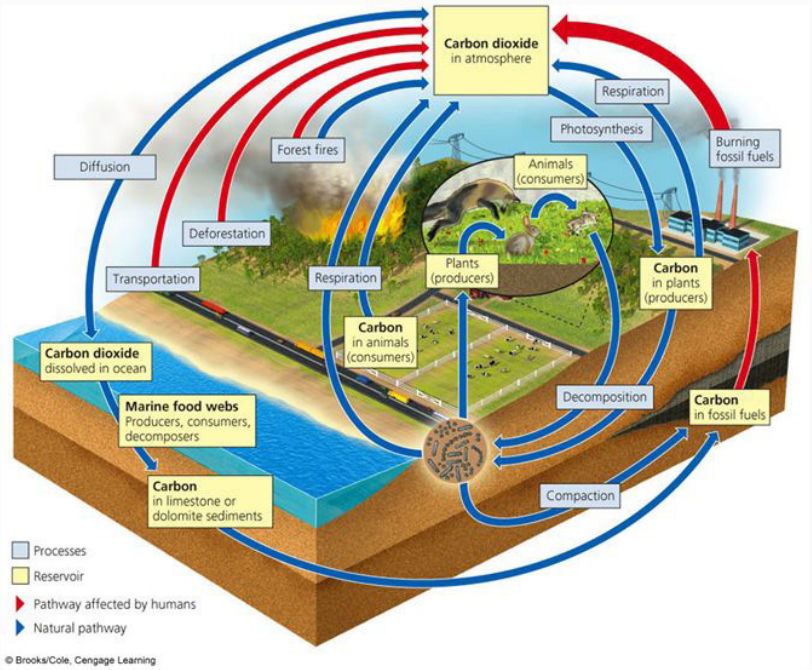


Natural Capital: Carbon Cycle with Major Harmful Impacts of Human Activities



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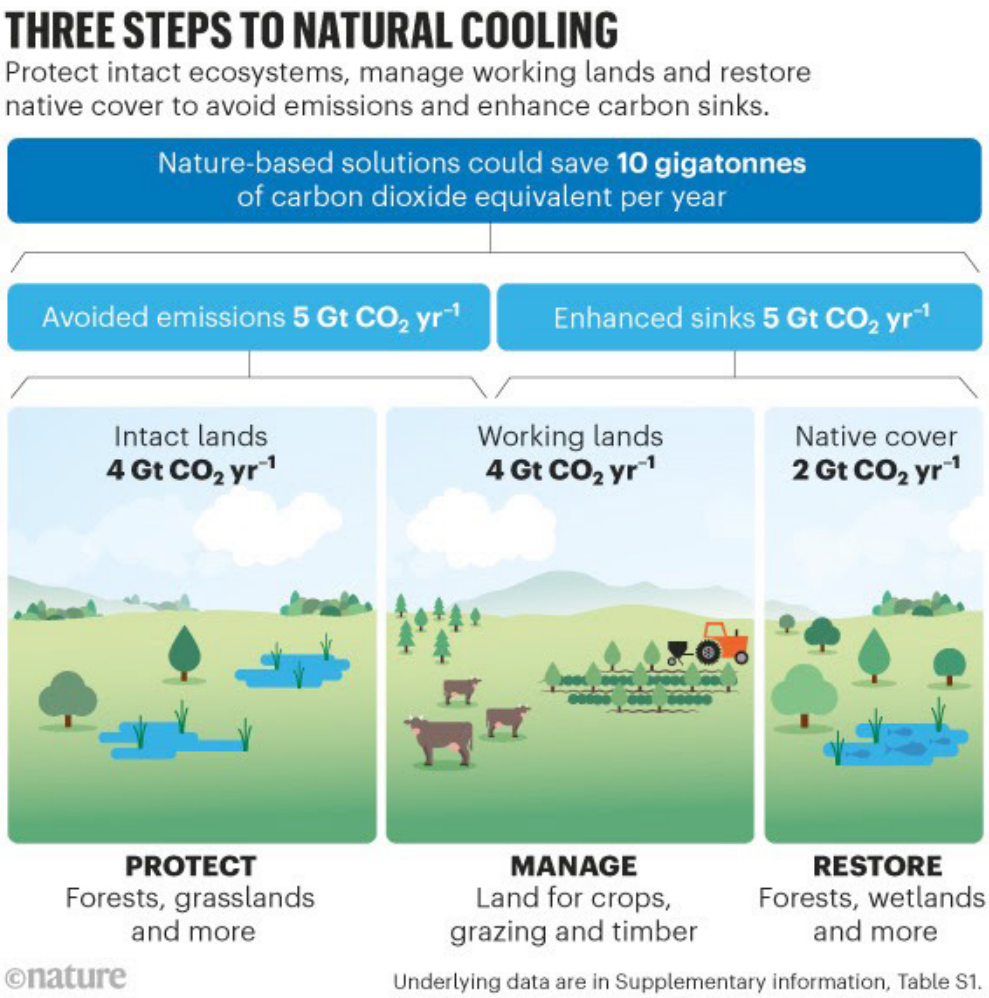

Figure 1a, b & c. Overview of the global carbon cycle. The stocks and fluxes of C (Gt) between various components and the atmosphere. Modified from Bhatti *et al.* [20]

Source: https://mail.google.com/mail/u/0/#inbox/FMfcgxwLttCBqCxzgtBhJLZNHRRHvMhQ.

and heterotrophic respiration; the latter being dominated by microbial decomposers. Until recently, exchanges of CO_2 between the land mass and the atmosphere (uptake in photosynthesis and release by respiration/decomposition) were believed to be nearly in equilibrium. However, more recent research suggests that the terrestrial surface is acting as a carbon sink, with a net uptake of CO_2 from the atmosphere [22].

Of considerable importance in the terrestrial carbon cycle is the relative proportions of carbon stored in soils and in living vegetation (biomass). Carbon stored in soils includes dead organic matter on the soil surface and in the underlying mineral soil. Estimates place the amount of soil carbon at 1500 Gt, compared with 560 Gt for the total world terrestrial biomass. Much of this carbon stored as dead organic matter is in the lower soil profile, where it exceeds carbon in the surface soil by a factor of 25. The lower soil layers of tropical forests and both tropical and temperate grasslands contain a large percentage of soil carbon, whereas soil carbon in temperate forests and Arctic regions is confined largely to the surface soil layers. The average amount of carbon per unit of soil profile increases from the tropical regions poleward to the boreal forest and tundra (Table 1). Low values for the tropical forest reflect high rates of decomposition, which compensate for high productivity and litterfall. Frozen tundra soil and waterlogged soils of swamps and marshes have the greatest accumulation of dead organic matter, because moisture, low temperature, or both inhibit decay. Soil carbon greatly exceeds biomass in boreal forests and tundra. Soil carbon likewise exceeds biomass in temperate grasslands, but in tropical savannas the reverse situation exists, probably because of recurring fires. World output of carbon from respiration resulting from the decompo-

sition of soil carbon in terrestrial ecosystems amounts to approximately 60 Gt per year.

The global cycle of atmospheric carbon dioxide, like local cycles, exhibits a marked annual variation, particularly in the land-dominated Northern Hemisphere. North of the 30ºN latitude, carbon dioxide content of the atmosphere up to the lower stratosphere begins to decline markedly during early spring, when photosynthetic activity and carbon storage in plant growth withdraw more carbon dioxide from the atmosphere than is replaced by respiration. The concentration of carbon dioxide reaches a low in August. By October the level increases again as photosynthesis declines and respiration dominates the exchange between the atmosphere and terrestrial ecosystems. The difference in the magnitude of the seasonal oscillation of CO_2 between the Northern and Southern Hemispheres reflects the difference in the land mass of the two hemispheres.

2.2 Human impact on the carbon cycle

The CO_2 flux among land, sea and atmosphere has been disturbed by a rapid injection of carbon dioxide in the atmosphere from the burning of fossil fuels and from the clearing of forests [1-3]. Clearing increases the input of CO_2 from burning trees and decomposing organic matter [3,8]. Adding to the problem of increasing carbon dioxide are increases in other atmospheric gases, especially methane (CH_4). Its major sources are ruminant animals, microbial decomposition in swamps, marshes and tundra and industrial gases released to the atmosphere [24-27]. Over time (resident time of 3.2 years) methane oxidizes to H_2O, especially in the stratosphere. Atmospheric methane has approximately doubled over the past 200 years. This increase is linked to human population growth and to increased cattle ranching and rice paddy production. The rising atmospheric concentrations to CO_2 and methane have the potential to alter the global energy balance and subsequently the global climate system. The implication of rising atmospheric concentrations of CO_2 and possible climate change [6,7,27]. Human activity has led to an enhanced rate of output of carbon into the atmosphere which has caused a measurable rise in the concentration of atmospheric CO_2. This is due to increased use of organic matter, coal, petroleum and natural gas as fuel and the combustion of carbonate rocks for the manufacture of cement and lime [28]. Rapidly growing human population is also modifying the natural ecosystems over an increasingly larger area of earth's surface by extensive deforestation, faulty agricultural practices, intensive grazing etc [1-3,8]. The universally distributed poisons like lead and DDT tend to depress the photosynthesis efficiency of green plants on global scale. So, while there are more inputs of CO_2 in the atmosphere its output is somewhat reduced. We have a little more than 5500 x 10^9 metric tons of carbon locked in fossil fuels, which represent photosynthesis of past ages. Today about 835 x 10^9 metric tons of carbon is locked in the biosphere and the atmosphere contains about 725 x 10^9 metric tons of carbon as CO_2. No wonder between the years 1880 AD

Table 1. Distribution of Detritus and Biomass by Ecosystem Types

Ecosystem Type	Mean Total Profile Detritus (kg C/m^2)	CV (%)	World Area (10^9 ha)	Total World Detritus (10^9 mtn C)	Total World Biomass (10^9 mtn C)
Woodland and shrubland	6.9	59	8.5	59	22.0
Tropical savanna	3.7	87	15.0	56	27.0
Tropical forest	10.4	44	24.5	255	460.0
Temperate forest	11.8	35	12.0	142	175.0
Boreal forest	14.9	53	12.0	179	108.0
Temperate grassland	19.2	25	9.0	173	6.3
Tundra and alpine	21.6	68	8.0	173	2.4
Desert scrub	5.6	38	18.0	101	5.4
Extreme desert	0.1	-	24.0	3	0.2
Cultivated land	12.7	-	14.0	178	7.0
Swamp and march	68.6	63	2.0	137	13.6
Total			147.0	1456	826.9

CV = coefficient of variation = standard deviation/mean x 100

Source: Adapted from Schlesinger [23]

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to 1960 AD the total mass of carbon in earth's atmosphere rose by 12.14% of which about 150 x 10^9 metric tons has been introduced as a result of burning of fossil fuel alone.

3. Global Nitrogen Cycle

3.1 Main features

The global nitrogen cycle follows the pathway of the local nitrogen cycle, only on a grander scale. The global cycle is diagrammed in Figure 2. The atmosphere is the largest pool, containing 3.9 x 10^{21} g. Comparatively small amounts of nitrogen are found in the biomass (3.5-10^{15} g) of terrestrial ecosystems [29,30]. The major sources of fixed nitrogen are biological (140 x 1012 g yr^{-1}) and high-energy fixation of atmospheric nitrogen by lightning > 3 x 10^{12} g yr^{-1}) [31,20]. Additional sources of nitrogen include inorganic nitrogen in rain, from such sources as fixed juvenile nitrogen from volcanic activity; absorption of ammonia from the atmosphere by plants and soil; and nitrogen accretion from windblown aerosols, which contain both organic and inorganic forms of nitrogen. In terrestrial ecosystems, ammonia and nitrates are taken up by plants and converted to organic nitrogen (amino acids) and moved through the food chain [31,20]. Dead organic matter is broken down into ammonia, then into nitrates and nitrites. Nitrates may be taken up directly by plants, immobilized by microbes, stored in decomposing humus, or leached into streams, lakes, and eventually seas. The uptake of inorganic nitrogen by plants is so rapid that at any given time, the pool of inorganic nitrogen (NH_4^+ and NO_3^-) in soils is very small. Most of the nitrogen stored in terrestrial ecosystems is tied up in organic matter, both living and dead [31]. Global estimates of denitrification in terrestrial ecosystems vary widely but are on the order of < 200 x 10^{12} g yr^{-1}, of which over half occurs in wetland ecosystems [29]. The major sources of nitrogen to the world's oceans are dissolved forms in the freshwater drainage from rivers (36 x 10^{12} g yr^{-1}) and inputs in precipitation (30 x 10^{12} g yr^{-1}) [33]. Biological fixation accounts for another 15 x 10^{12} g yr^{-1} [31]. In aquatic ecosystems, nitrogen is cycled internally in a similar manner to that discussed for terrestrial ecosystems, except that the large reserves, such as those contained in soil humus, are lacking. Life in the water contributes organic matter and dead organisms that undergo decomposition and subsequent release of ammonia and nitrates.

Tracer studies with ^{15}N, a stable, nonradioactive isotope, show that in marine ecosystems, ammonia is recycled rapidly by phytoplankton [31]. As a result, little ammonia exists in natural waters, and nitrates is used only in the virtual absence of ammonia. There are small but steady

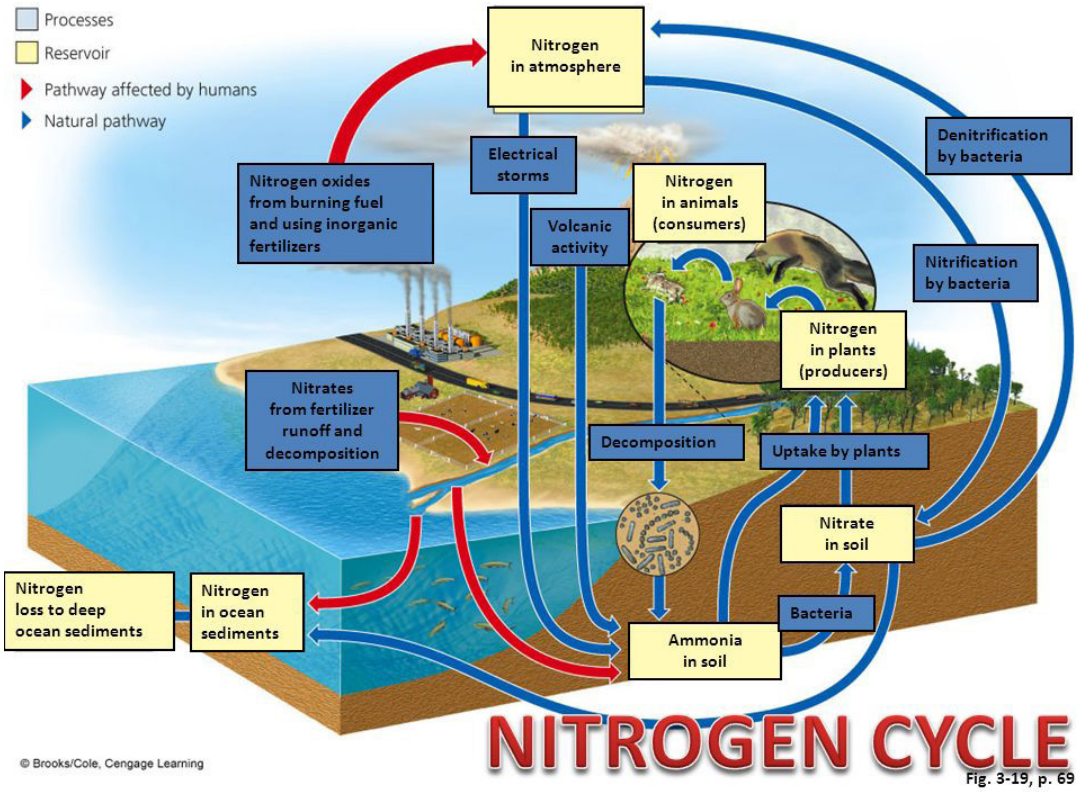

Figure 2. Overview of the global Nitrogen cycle.

losses from the biosphere to the deep sediments of the ocean and to sedimentary rocks. In return there is a small addition of new nitrogen from the weathering of igneous rocks and juvenile nitrogen from volcanic activity. Denitrification accounts for an estimated flux of 110 x 10^{12} g N yr^{-1} from the world's oceans to the atmosphere.

3.2 Human impact on the nitrogen cycle

Under different circumstances, human intrusions into the nitrogen cycle result in either a reduction on an increase in nitrogen availability. Conversion of forests and grasslands to cropland results in a steady decline in nitrogen content of the soil. Mixing and breaking up the soil exposes more organic matter to rapid decomposition and leaching from the soil. Removal of nitrogen through harvested crops and grazing causes additional losses. On the other hand, excessive amounts of nitrogen may be added to the system, creating a variety of problems. Heavy applications of commercial fertilizer disturb the natural balance between fixation and denitrification by reducing the former and increasing the latter. A considerable portion of the added nitrogen may be leached to the groundwater as nitrates [18,34-36]. Animal wastes, especially from livestock concentrated in large feedlots, are another source of nitrates in groundwater. Excessive quantities of nitrates in groundwater become health endangering pollutants [18,34-36].

A third source of nitrate pollution is human waste, particularly sewage, treated or otherwise, released into rivers, lakes and estuaries [37]. In spite of the magnitude of water pollution from agricultural sources, human effluents contribute even heavier loads, especially from municipal sewage treatment. Automobiles and power plants are the major sources of nitrogenous pollutants in the atmosphere, particularly nitrogen oxides [9,38]. Current estimates place nitrogen emissions due to automobiles, factories, power plants and other combustion processes at 20 x 10^{12} g N yr^{-1}. The primary nitrogenous air pollutant is nitrogen dioxide (NO_2), a pungent gas that produces a brownish haze. In the atmosphere, nitrogen dioxide is reduced by ultraviolet light to nitrogen monoxide and atomic oxygen:

$$NO_2 \longrightarrow NO + O$$

Atomic oxygen reacts with molecular oxygen to form ozone:

$$O_2 + O \longrightarrow O_3$$

Ozone, in a never-ending cycle, reacts with nitrogen monoxide to form nitrogen dioxide and oxygen:

$$NO_2 + O_3 \longrightarrow NO_2 + O_2$$

This cycle illustrates only a few of the reactions that nitrogen oxides undergo or trigger. In the presence of sunlight, atomic oxygen from nitrogen dioxide also reacts with a number of reactive hydrocarbons to form radicals. These radicals then take part in a series of reactions to form still more radicals that combine with oxygen, hydrocarbons, and nitrogen dioxide. As a result, nitrogen dioxide is regenerated, nitrogen monoxide disappears, ozone accumulates and a number of secondary pollutants form, including formaldehydes, aldehydes, and peroxyacylnitrates, known as PAN. All of these pollutants especially PAN, and ozone are very toxic and injury many forms of plant life exposed to them. One outcome of nitrogenous atmospheric pollution is an increased deposition of nitrogen, which benefits ecosystems that are traditionally nitrogen-limited, especially northern and high-altitude forests. Such ecosystems, however, can suffer from too much of a good thing. Because under natural conditions nitrogen is limiting, these forests are efficient at retaining and recycling nitrogen from precipitation and organic matter. Significant export of nitrates to stream is seldom seen. However, many of these forests are receiving more nitrogen in the form of ammonium and nitrates than the trees and their associated microbial populations can handle and accumulated, a condition referred to as nitrogen saturation. Under these conditions, excess nitrogen, particularly in the form of nitrate, leached into surface waters.

The first response to increased availability of nitrogen in a nitrogen-limited ecosystem is increased growth of both canopy and stems. Evidence suggests, however, that increased levels of nitrogen can lead to the decline and dieback of coniferous forests at high elevations [20]. If the increased growth in foliage continues into late summer, the late new growth may not have time to become frost-hardened and is killed during the winter. Overstimulated by nitrogen, tree growth exceeds the availability of other necessary nutrient in the soil, particularly phosphorus, and the tree begins to experience nutrients deficiencies. Experimental evidence suggests that the production of fine roots and ectomycorrhiza, which take up nutrient deficiencies. Experimental evidence suggests that the production of fine roots and ectomycorrhiza, which take up nutrients from the soil, is lower on sites rich in nutrients, especially nitrogen, than in nutrient-poor soils, and root turnover is higher. Trees on nutrient -poor soil have a longer-lived and higher density root system and a lower turnover of root biomass. These conditions help the trees to scavenge nutrients from poor soils. As nitrogen levels increase, root biomass decreases because sufficient nitrogen is nearby. A smaller root biomass then inhibits the uptake of nutrients other than nitrogen and impairs the ability of tress to pull water from then soil during periods of drought. As nitrogen deposition increases, ammonium levels in the soil increase. Excess ammonium in the soil

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stimulates nitrification, denitrification, and mobility of nitrates in the soil, even at a low pH. As excess nitrates are leached from the soil, they increase anion movement through the soil, releasing aluminium (AI^{3+}). As has been observed in the spruce stands of the Great Smoky Mountains. This aluminium finds its way to aquatic ecosystems, increasing their acidification.

4. Hydrological Cycle

4.1 Main features

Figure 3a & b represents a conceptual model of the hydrologic cycle and shows Earth's water movement between the ocean, land, and atmosphere. As with all cycles, it is ongoing and continuous, and there is no specific start or end point. Precipitation is water released from the atmosphere in the form of rain, snow, sleet or hail. During precipitation, some of the moisture is evaporated back into the atmosphere before ever reaching the ground. Some precipitation is intercepted by plants, a portion infiltrates the ground, and the remainder flows off the land into lakes, rivers, or oceans. An important difference between the roles of snow and rain is that runoff occurs relatively quickly following the rain event, whereas snow usually melts much more slowly over days, weeks, or months. The subsequent surge of snowmelt runoff can provide seasonal recharge to groundwater resources but can also trigger flood conditions if the snowmelt occurs too rapidly and in excessive amounts [39]. In addition, the solid snow or ice may change directly into a gas, skipping the liquid state, in the process called sublimation. When precipitation is intercepted by plants, it is eventually evaporated back to the atmosphere. When it infiltrates the ground, it can be taken up by roots and transpired by plants, it can be evaporated from the soil, or it may recharge an aquifer.

The water in an aquifer is called groundwater, and its rate of flow in the subsurface is such that water can reside in aquifers for days to centuries before discharging to a surface body of water (e.g., river, lake, and ocean). Once groundwater has been discharged into a river, lake, or ocean, the surface of the water body is exposed for evaporation, causing moisture to collect and concentrate in the atmosphere, eventually returning to the earth as precipitation as the cycle begins again. In addition to natural discharge, groundwater can more rapidly discharge when an aquifer is pumped. With the advent of motorized pumps, the rapid removal of groundwater from aquifers is a relatively recent phenomenon that has greatly affected the depletion of the aquifers and the water balance of many catchments [33].

Despite the fact, the hydrological cycle is a continuous process. It is by no means universal all over the globe: the water residence time differs repeatedly dramatically between diverse cycle of portions. For instance, water is uninterruptedly evaporated from the surface of water bodies (e.g., oceans, lakes, as well as rivers). Likewise, rainfall that is interrupted through plants as well as other surfaces is frequently evaporated within hours. After evaporation, an average of 10 days is taken for a water molecule to go round the atmosphere, but if it infiltrates to the water table, or if the precipitation occurs in a polar region, it can take decade of years before transferring to another phase next in the water hydrologic cycle. Besides the variable residence periods, the processes related to the hydrologic cycle are not distributed evenly over the earth; they differ in climatic region [33]. For instance, rapid evapotranspiration can occur in semi-arid and arid areas. Nonetheless successive rainfall might not happen within the same region or basin. The dramatic changes in how the cycle operates are particularly evident as soon as the hydrologic cycle is evaluated at the level of catchment scale.

4.2 Human impact on the hydrological cycle

The past human activity interaction, including hydrological balance, has led to the exploitation of irrigation systems, as well as in the contemporary urbanization period. Irrigation systems of this kind, using water from stream network as well as larger canals systems have become characteristic of India great hydraulic societies [33]. But then again, the population pressures as well as industry on urbanization over the past three years has led to the irrigation demand extension as well as water services in novel areas. This often seems to lead toward integration of isolated system in the drainage basin. Activity of humans has disrupted all parts of the water cycle; runoff is deposited in huge reservoirs behind dams, transpiration losses reduced through deforestation, groundwater is filled with water spreading as well as pumping. Human activity impact in Table 1 shows diverse major basins drainage in South India as well as their hydrogeological and hydrological features. The unplanned pattern of irrigation as well as past agricultural methods in South India have made effective management of water very difficult. Large shallow tanks previously built remain at the moment being silted up rendering irrigation useless. Canals losses through seepage as well as drains remain heavy. Most South India wells, dug in the hard rock zones, are mostly shallow (There are tube wells in soft alluvium in riverine areas). The depth, diameter as well as large wells spacing have not yet been methodically studied for optimum utilization. The South India irrigation wells collapsed due to a rising depression cone in water table. Because of these water management shortcomings through human agency,

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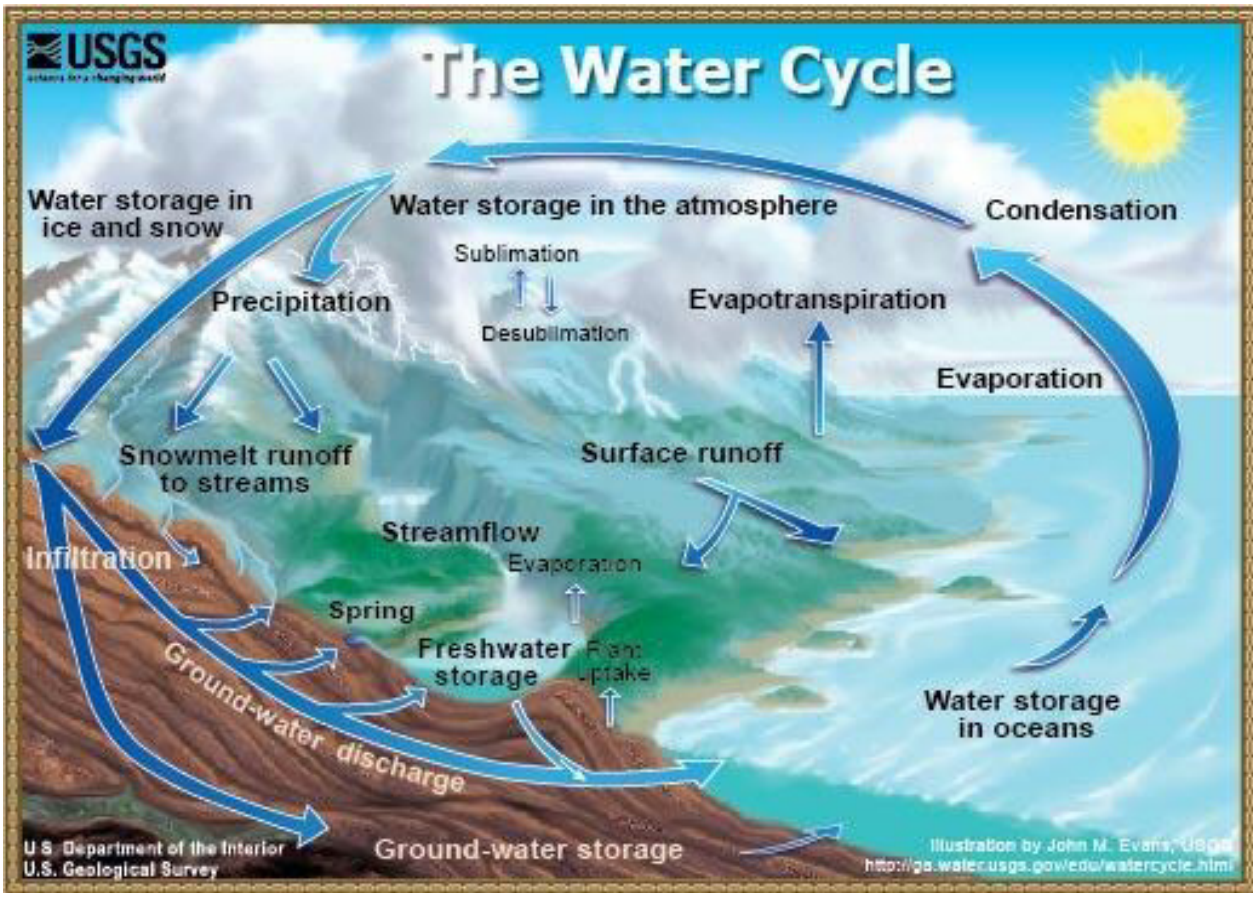

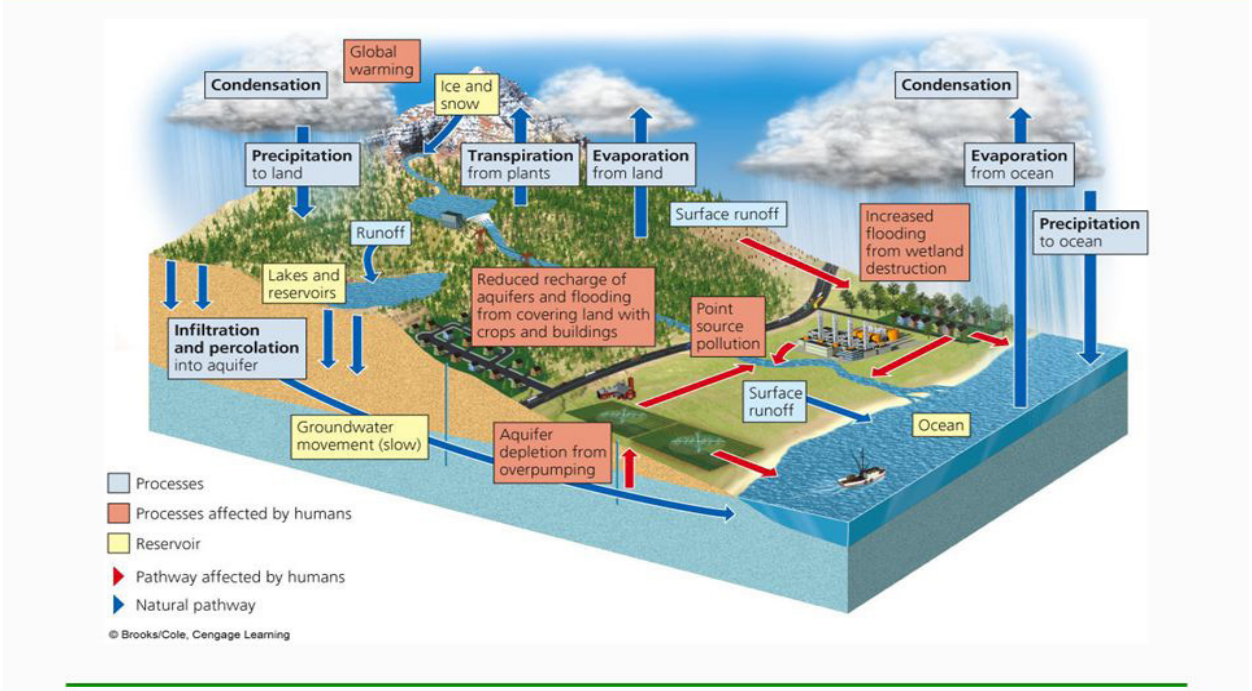

Figure 3a & b. Schematic representation of the hydrologic cycle. (USGS)

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various parts of the interior of South India are frequently drought as well as famine stricken. There are various rural areas where individuals have to travel several miles for water. A systematic future development plan for water resources in South India is instantly obligatory toward ensuring adequate supplies.

4.3. Global hydrological cycle

Earth's majority water (approximately 1.4 billion cubic meters or 96.5% of all resources) is found in oceans. Continental water accounts for approximately 3.5% of world's water supply; nevertheless, approximately three-quarters of that percentage (29 million cubic kilometers) exists as polar ice caps as well as glaciers, and deep groundwater is approximately 5.3 million cubic kilometers. Hence, only other fractions can enter the water exchange amongst the atmosphere, oceans, as well as the continents. This residue part comprises deep groundwater as well as soil moisture (approximately 4.3 million cubic kilometers); water from reservoirs, lakes, as well as swamps (0.125 million cubic kilometers); storage of water in river channels (2.1 thousand cubic kilometers); water from biosphere (approximately 0.6 thousand cubic kilometers). The atmospheric amount is only 0.013 million cubic kilometers (0.001%). The main global mechanisms as well as terrestrial water cycles remain the water exchange amongst the atmosphere as well as the oceans, the earth's surface and amongst continents. The most important sources of energy exchange today are solar radiation as well as gravitational force. Yearly, the earth's surface disperses water, approximately 580,000 cubic kilometers. The required energy toward converting this sum of water into steam vapor matches up to 36% of solar energy absorbed through the entire earth. Approximately 85% of the total world-wide evaporation comes from the surface of the ocean as well as the rest comes from the evaporation of the land surface. The average yearly moisture content on the surface ocean unit area is 1400 mm; moreover, this land surface value is only 485 mm (roughly three times lower). Averagely, evaporating water stays in the atmosphere for approximately 8 - 10 days, due to air moisture condensation, majority of the dispersed water falls back to the earth's surface as snow or rain. The total yearly rainfall on the surface of the earth's is roughly proportional to the whole global evaporation. Nevertheless, the total yearly ocean surface evaporation is greater than the amount of rainfall. The evaporated water surplus (approximately 47,000 cubic kilometers) is carried through air currents resulting from oceans to continents [33]. Approximately 40% of the continent's rainfall returned to the oceans as river runoff (roughly 450,000 cubic kilometers), or groundwater that flows directly into the oceans (around 20,000 cubic kilometers). The rest reevaporates as well as returned to the ground. On average, transported water from the oceans is recycled as well as precipitated 2.7 times ashore before returning back to oceans.

4.4 Human influence on the terrestrial hydrological cycle

Activities of human alter the river basins land cover as well as remain intended at regulating fluxes of water in nature, which can significantly transform the water cycle of a separate river basins, as well as large regions. An outstanding instance of this modification is the current circumstances in Aral Sea basin, where thorough irrigation has occasioned in virtually complete water inflow cessation that cross the Syr-Darya River as well as the Amu-Darya River, along with drastic drop in sea level from the Aral. Other well-documented illustrations consist of risks of increased drought in the Mediterranean as well as the Sahel, following vegetation removal through deforestation as well as corresponding over exploitation. There is likewise indications that significant scale of change as well as flooding frequency in the Ganges basin might remain described through forest clearing in the rural mountainous area. Due to the activities of human, the natural river basins water cycle is becoming increasingly transformed as well as regimented. The major regulation methods of stream flow are dams, barrages, levees, as well as dikes construction, which offer accumulation of water, increasing low flow, as well as flood flow decrease. The main impact on the construction reservoir on water cycle (except runoff control) is to increase evaporation as well as groundwater table rise. In arid areas, losses resulting from evaporation of reservoir water surface might remain so huge that they extremely compromise somewhat possible gains. Equally, in moderate climate conditions, the losses from evaporation reservoir remain comparatively small. For example, reservoirs evaporation from Volga River basin (where approximately 300 reservoirs of storage capacity which can reach over 1,000,000 cubic meters) found a reduction of 3 - 5% of the Volga River runoff. Level of groundwater rise in the reservoir periphery as well as along the changes nearby the runoff mechanism generation in these areas. Steady river flow regime changes may happen due to a decreasing consequence of river's carrying capacity toward transporting sediments, particularly from above as well as in reservoirs. Sediment input reduction at the site of the dam decreases the channel of river slope as well as the bed sheer pressure, leading to falling flow velocities as well as river meandering development. The irrigation impact on water cycle is particu-

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larly revealing in dry areas, nevertheless it is likewise significant in areas with favorable climatic conditions where irrigation activities is of supplementary character. Water diversion of irrigation purposes resulting from ground or surface water resources alters the processes of natural hydrological. Common runoff as well as evaporation resulting from areas irrigated upsurge significantly. River basins irrigation where there is no additional method of supply frequently leading toward reduction of runoff in the outlet site. In several arid regions, a substantial increase in groundwater table could happen due to filtration of water from reservoirs, water distributing systems leakages, as well as defective irrigation technology. Such an increase can lead to plants waterlogging as well as soil development salinization.

Removal of surplus water from soils that is waterlogged, drainage systems are used in several world regions. The prime drainage effect remains the groundwater table lowering as well as extend the layer through soil that are unsaturated. As a consequence, evapotranspiration can be significantly reduced (by over 50% in some cases). The enhancement of hydraulic conditions from increase drainage flow velocities. After construction in the first years of a drainage system, the yearly increase runoff is 20 to 30%. Particularly huge increase in runoff could be detected all through the months of low runoff in winter as well as summer. Flow acceleration likewise leads toward a remarkable flood peaks increase. After roughly 10 to 15 years, the drainage impact on runoff declines. Due to groundwater quality, which is generally higher than surface water, as well as its relative constant temperature, huge groundwater volumes remain extracted in some parts of the world for domestic, industrial as well as agricultural use (see Figure 4, 5, 6 & 7 below) [1,5,18,27,34-36,40-44].

When groundwater is taken from a confined aquifer beneath impermeable layers, groundwater table remains only somewhat impacted, as most contaminants originate from human activities such as industrial processes and mining, poor waste management, unsustainable farming practices, accidents ranging from small chemical spills to accidents at nuclear power plants, and the many effects of armed conflicts. Pollution knows no borders: contaminants are spread throughout terrestrial and aquatic ecosystems and many are distributed globally by atmospheric transport. Indeed, pollution tends to affects above and below ground biodiversity, both by reducing the number of organisms due to the toxicity caused by the contaminants, as well as by producing changes in communities, due to the replacement of more sensitive species by more pollution-tolerant ones. Low concentrations of contaminants often lead to adaptive strategies through changes in physiology and feeding behaviours. Changes in the activity of soil organisms can also occur, resulting in the alteration of biogeochemical cycles. Additionally, polluted soils in turn become a source of pollution for groundwater, through leaching of contaminants, and for fresh water and the marine environment, since contaminants can be transported off-site through wind and water erosion. All those changes can be gradual or remain inert until an inflexion point is reached and a severe degradation occurs. This triggers a chain of degradation processes in terrestrial and aquatic ecosystems that ultimately leads to the loss of ecosystem services (Figure 8).

In addition, in some river basins, the groundwater table frequently drops steeply, as well as this might decrease surface runoff as well as lower the level of small rivers. In several riverine regions, the groundwater extraction leads toward seawater disruption. With the water regime direct change of river basins through the control stream channel means, irrigation, drainage, as well as abstractions of groundwater, land use river basins changes can exert remarkable impact on the water cycle. The significances of the changes in land use might remain gradually exposed, as well as remain masked via climate variations. Nonetheless a vital hydrological transformation regime could happen. The utmost remarkable hydrological cycle distortions remain observed in urban areas, through natural land cover replacement with urban impermeable surface resulting in great decrease in infiltration as well as evapotranspiration. The precipitation runoff resulting from urban areas is usually produced as overland flow as well as quickly reaching into river drainage system. As a result, the amount of precipitation flood can increase many times, as well as the peaks of the hydrographs can be multiplied by 10 to 15 [20,31,33]. Equally, transporting snow can result in a snowmelt runoff decrease. Because of infiltration reduction as well as groundwater abstractions for water supply in urban area [40,41], groundwater table falls remain likewise observed in neighbourhood's urban areas. The agricultural effects as well as forestry practices on water cycle remain less apparent, as well as depend, to a remarkable extent, on the physiographic as well as climatic situations. It is clear that ploughing, particularly contour ploughing, often breaks up with overland flow as well as improves infiltration. Some distinct ploughing types can stretch the depression as well as storage detention on mild gradients from approximately 8 to 10mm (under natural conditions) up to 30 to 40mm. Tillage as well as the action of plant root systems altering the upper soil layer structure as well as vertical permeability changes, nonetheless the water holding capacity. The vegetation cover extension as well as leaves area increases precipitation interception

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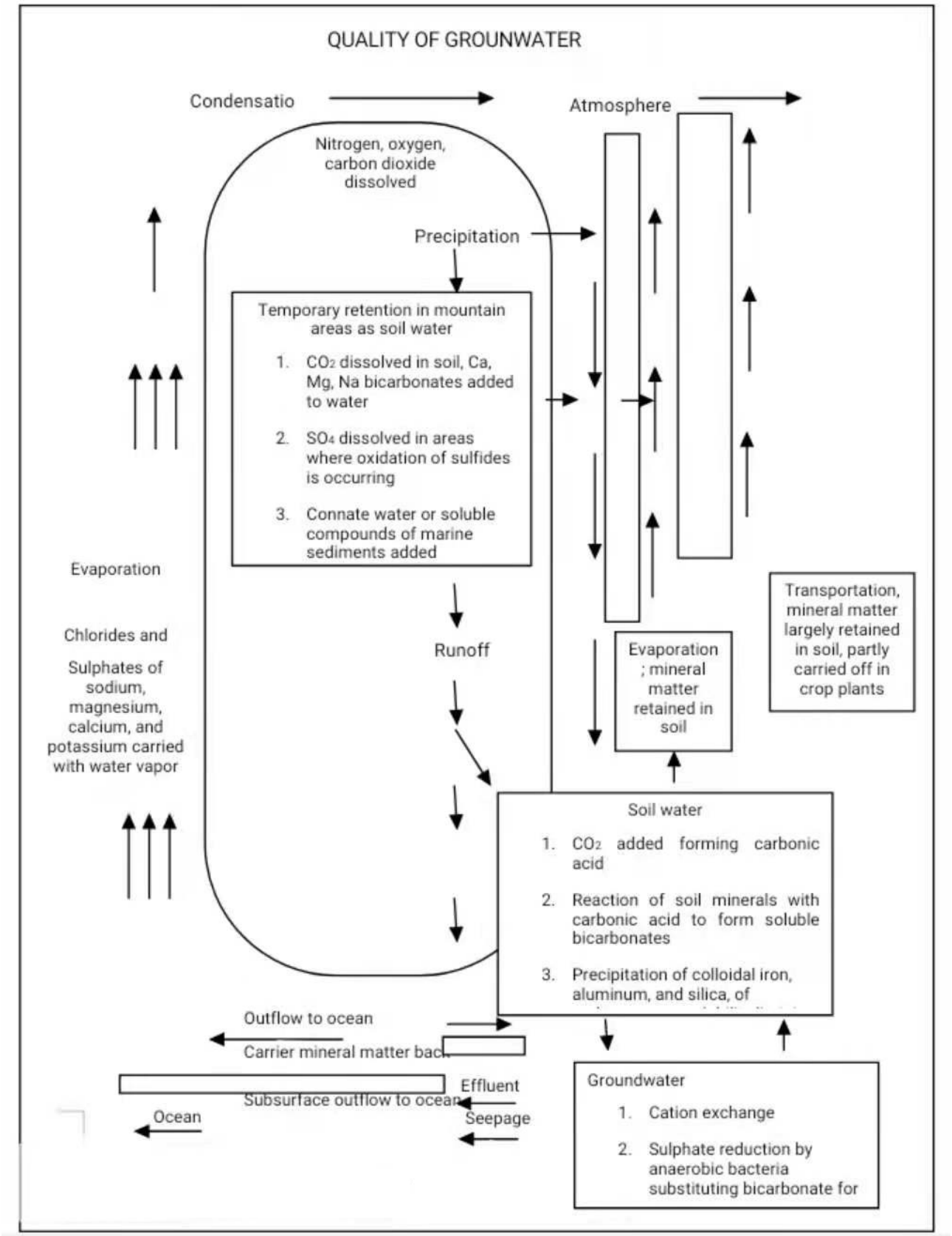

Figure 4. Geochemical cycle of surface water and groundwater (Adapted from David [45])

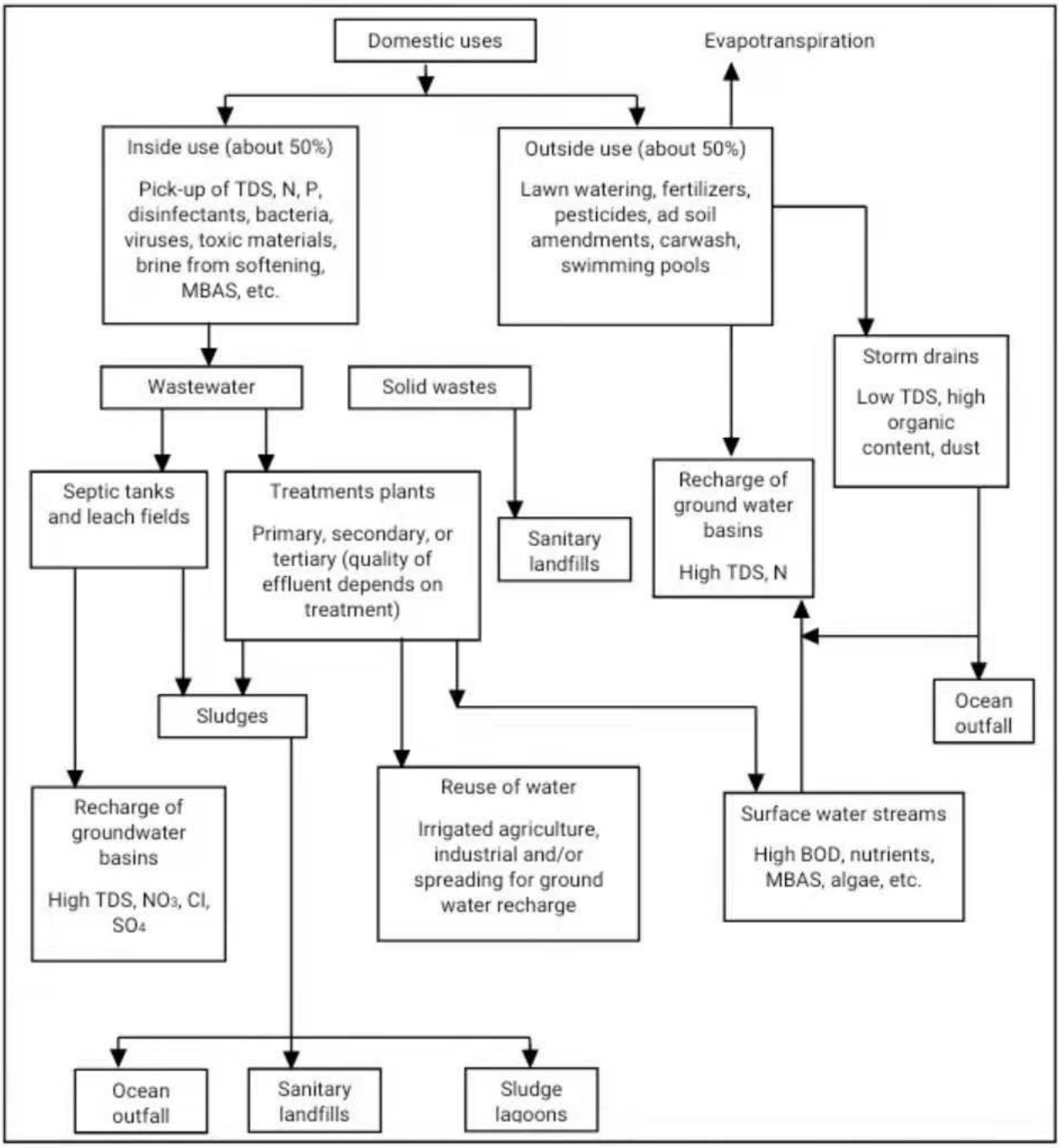

Figure 5. Domestic uses of water and their effects on water quality (Adapted from David, [45])

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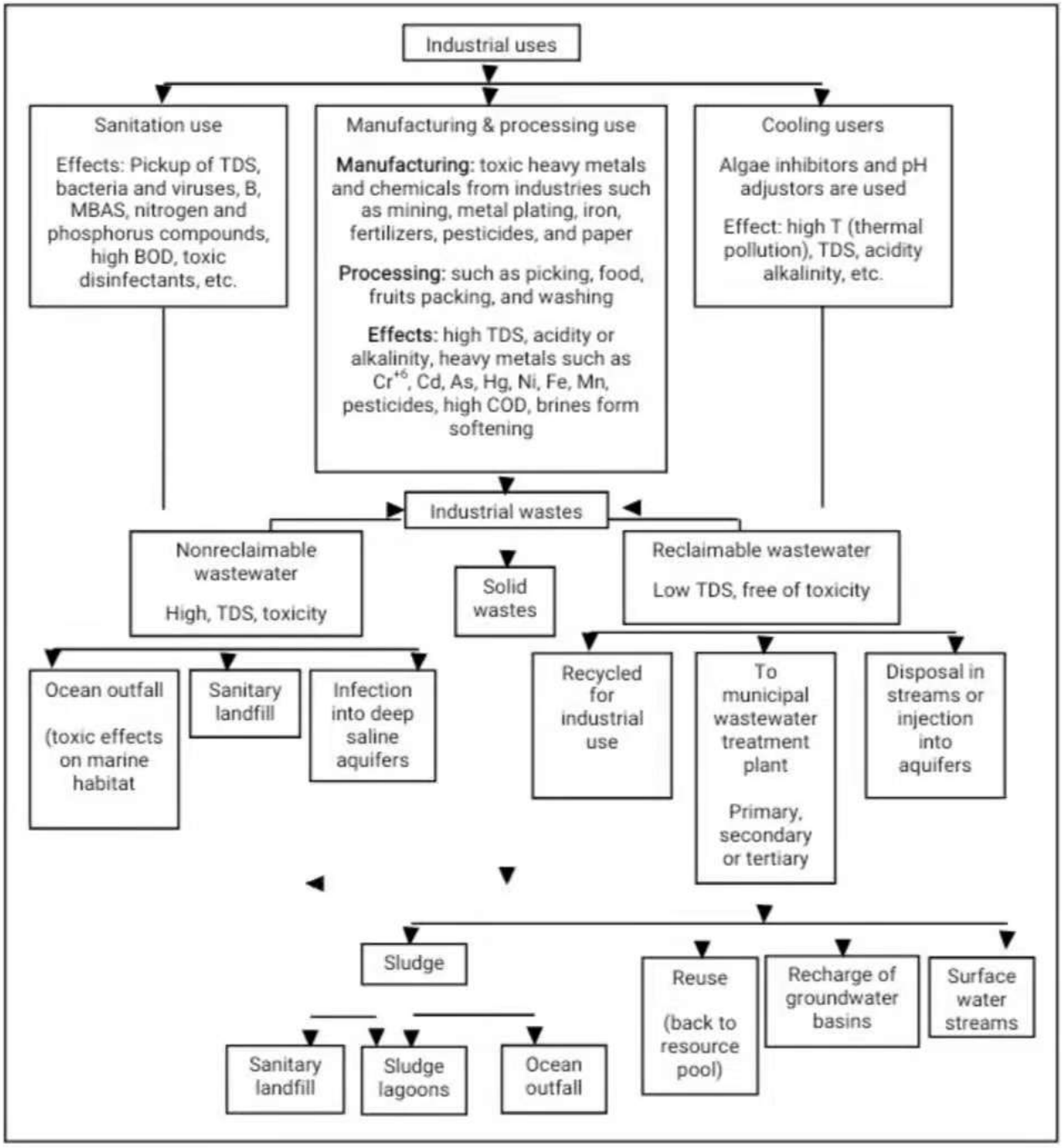

Figure 6. Industrial uses of water and their effects on water quality (Adapted from David [45])

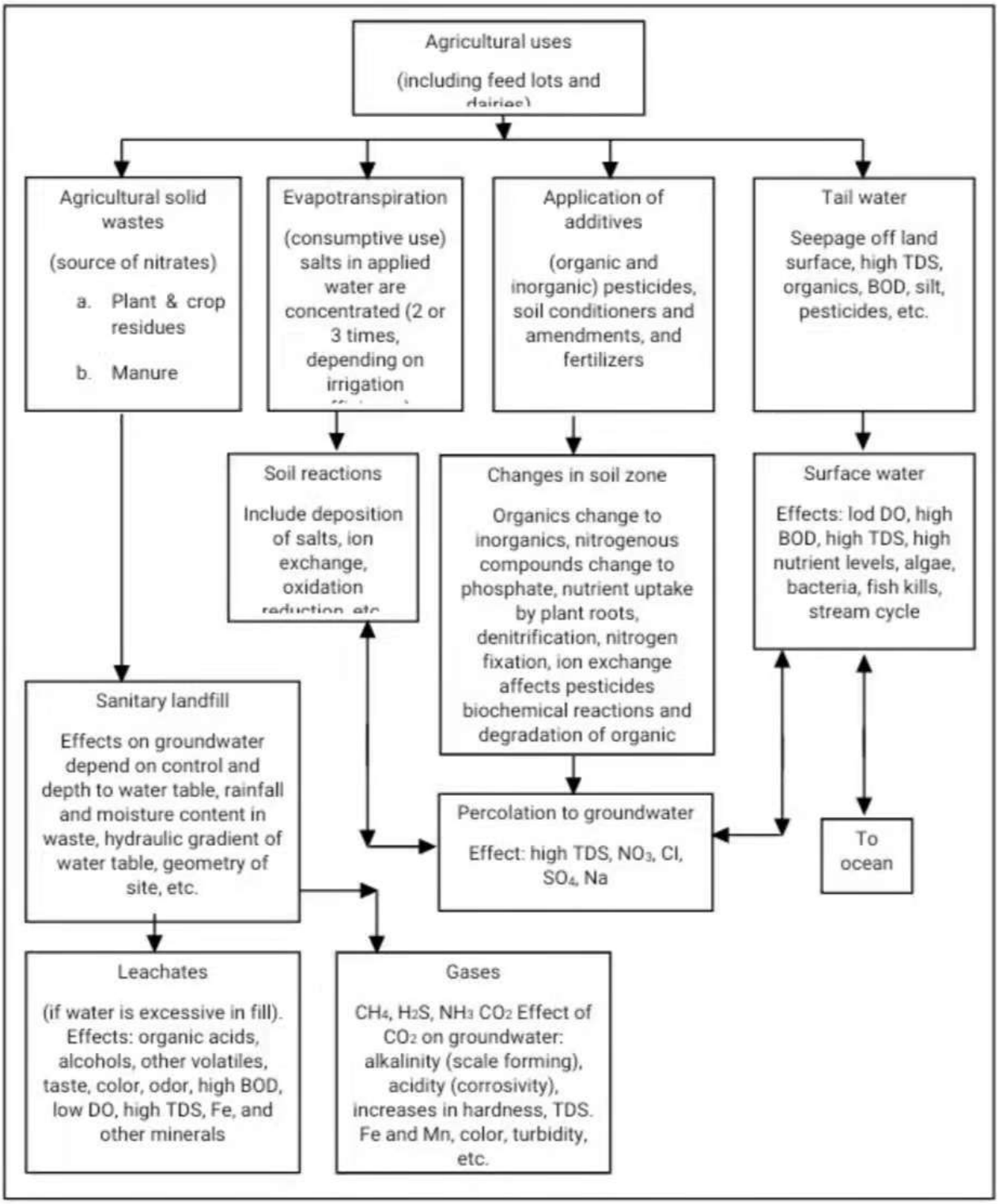

Figure 7. Agricultural uses of water and their effects on water quality (Adapted from David [45]).

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Figure 8. Soil pollution causes a cycle of degradation processes that leads to the reduction and ultimately to the loss of ecosystem services

Sources: Adapted from FAO and UNEP [46]

as well as evapotranspiration. Overland flow control of impenetrable permanent grasses on steeper gradients may decrease storm runoff resulting from small watersheds via 20 to 25%. Of course, the relative impact of all these changes yearly as well as flood runoff remains determined through river basin as well as climate features. In arid regions (for instance, steppe zone), the 15 to 20% yearly runoff changes triggered through agricultural practice have remained fixed, as well as over different years such changes reached 30 to 40%. Equally, in wet regions, particularly in forest as well as steppe zone in northern forest, the agricultural practices impact on runoff can be ignored. The results clearly show deforestation effects on water cycle of a river basin or increased transpiration as well as precipitation interception, which sequentially reduces total runoff volume. Deforestation decreases infiltration as well as improves overland flow conditions in the country. Accordingly, flooding as well as peak discharges might remarkably increase. Equally, forest soils with higher infiltration increases opportunity aimed at groundwater recharge, as well as small rivers flow tends to be especially more sustained, particularly to produce snowmelt runoff

such as when forests sustain continuous flow through snowmelt delaying. Rising groundwater table as well as ground runoff increase might increase the low flow of medium as well as large-sized rivers. This effect frequently led to the deduction that forests upsurge runoff [3,6,7]. Though, thorough research observations on the representative as well as experimental basins don't regularly agree with such inferences. For instance, the outcomes of (15) fifteen individual watershed-scale experiments, including several forest cutting rates, conducted by the Coweeta Hydrologic Laboratory in Southern Appalachia throughout 50 years, show deforestation increased while afforestation decreased yearly as well as monthly runoff, nonetheless responses magnitude remained extremely variable. It recognised that the actual response from streamflow toward cutting of forest remained inversely proportional toward input of solar energy (according to the evapotranspiration index). The monthly alteration runoff is in line with the evapotranspiration changes. By the lowest flow, the regular monthly runoff was approximately 100% larger in clear-cut forest than without uncut forest. Clear cutting is less effective at the moment on flow during winter as well as early spring. Long-term research observations have likewise revealed the strong evidence of the volume of runoff on vegetal cover type. Hardwood conversion to pine decreased yearly runoff via 25cm as well as produced important reductions of regular monthly runoff. Equally, deforestation has resulted to substantial upsurge in flooding. Comparable outcomes were also obtained in relation to the basis of analyzing data gotten in other physiographic contexts. Forest zone research carried out in European region of Russia have revealed that forest impact on evapotranspiration, as well as runoff remarkably depends on forest age. Cutting down old forest might not modify evaporation, as well as accumulation increase of snow might cause roughly growth of spring runoff. In several areas, forest cutting has led to a remarkable intensification in disastrous floods as well as also triggered severe soil erosion [2,3,6.7]. In addition, the process of urbanization often causes changes in groundwater levels as a result of decreased recharge and increased withdrawal. In rural areas water supplies are usually obtained from shallow wells, while most of the domestic wastewater is returned to the ground through cesspools or septic tanks. Thus, a quantitative balance in the hydrologic system remains. As population increase, many individual wells are abandoned in favour of deeper public wells. Later, with the introduction of sewer systems, storms water and wastewater typically discharge to a nearby surface water body. Thus, three conditions disrupt the subsurface hydrologic balance and produce decline in groundwater levels;

i. Reduced groundwater recharge due to paved surface areas and storm servers.
ii. Increased groundwater discharge by pumping wells.
iii. Decreased groundwater recharge due to export of water collected by sanitary servers.

Here the above conditions have all been present leaching not only to a decline in water tables but also to groundwater pollution, seawater intrusion and reduced streamflow.

6. Conclusions

The COVID-19 crisis has reiterated the importance of biogeochemical cycles by highlighting the linkages between biogeochemical cycles and human health [47-49,53,54]. Human activity has degraded ecosystems as well as ecological barriers which would normally limit disease transfer [18,41-44]. As countries seek to build back better from the pandemic, biogeochemical cycles, biodiversity conservation and nature-based investment solutions is essential [50-52]. Thus, the carbon budget of the Earth is meticulously connected to the atmosphere, oceans as well as land and to the mass air movements round the planet. In the oceans, the surface water acts as the main site of exchange of carbon amongst atmosphere and ocean. The surface water's ability to absorb CO_2 is overseen largely by CO_2 reaction with the carbonate ion to create bicarbonates. The uptake of CO_2 from the atmosphere by terrestrial ecosystems is governed by gross production (photosynthesis). Losses are a function of autotrophic and heterotrophic respiration; the latter being dominated by microbial decomposers. Human pour nitrogen dioxide into the atmosphere and nitrates into aquatic ecosystems. The major sources of nitrogen oxides are automobiles and power plants. Nitrogen dioxide is then converted through ultraviolet light in the direction of nitrogen monoxide as well as atomic oxygen. These substances react with hydrocarbons in the atmosphere to produce a number of pollutants, including ozone and PAN. Both PAN and ozone make up photochemical smog, a pollutant harmful to plants and animals. Excessive quantities of nitrates are added to aquatic ecosystems by improper use of nitrogen fertilizer on agricultural crops, by animal wastes, and by sewage effluents. Nitrogen oxides have also been implicated in forest decline. Thus, water is important to the milieu as well as is well-thought-out to be nature drivers. All studies relating to water remain concerned with portion of the water cycle. The occurrence as well as water availability is thoroughly associated with human advancement. Due to several activities of humans, the characteristics/features of several water cycle components are experienc-

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ing changes, which can lead to long-term climate change. It is obligatory toward predicting the magnitude as well as extent of these variations so that vital ameliorative measures could be originated in time. Hence, the disturbances of the balance of biogeochemical cycle resulting from human activities hinders the achievement of many of the United Nations Sustainable Development Goals (SDGs), including those related to poverty elimination (SDG 1), zero hunger (SDG 2) and good health and wellbeing (SDG 3). Also, it hits the most vulnerable hardest, especially children and women (SDG 5). The supply of safe drinking water is threatened by the leaching of contaminants into groundwater and runoff (SDG 6). Furthermore, CO_2 and N_2O emissions accelerate climate change (SDG 13) and contribute to land degradation and loss of terrestrial (SDG 15) and aquatic (SDG 14) biodiversity, and decreased security and resilience of cities (SDG 11), among others. As the support for all terrestrial life is involved in the regulation and provision of many key ecosystem services that are essential to the environment and to human health and well-being. Thus, a transformative approach that is in line with the 2030 Agenda for Sustainable Development, which sets out to achieve socio-economic development, while conserving the environment is remarkable.

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Competing Interests

We affirm that we have no conflict of interest that may be alleged as prejudicing the impartiality of the study reported. This researcher did not receive special assistance from government, not-for-profit sectors or commercial institutions.

Consent

All the authors announced that they had received written notice from the participants.

Disclosure Statement

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