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Review: Biogeochemical process in mangrove ecosystem

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Abstract. *Aprilia DA, Dianti, Arifiani KN, Cahyaningsih AP, Kusumaningrum L, Sarno, Rahim KAA, Setyawan AD. 2020. Review: Biogeochemical process in mangrove ecosystem. Intl J Bonorowo Wetlands 10: 126-141.* The mangrove ecosystem, one of the unique and distinctive aquatic ecosystems, is located in the tidal areas of the coast coastal areas in the tropics and subtropics. Mangrove ecosystems have many ecological, environmental, and social benefits. Mangrove forests have the potential to become a potential resource. This review aims to determine the process and function of the biogeochemical cycle in the mangrove ecosystem. The research method used in this research is descriptive qualitative research methods and tends to use inductive analysis. The biogeochemical cycle acts as a cycle that cannot be separated from the mangrove ecosystem. Biogeochemistry is the process of circulating chemical elements or compounds that occur repeatedly and continuously. Biogeochemistry plays a role in maintaining environmental stability and maintaining life on earth. The biogeochemical cycle consists of energy flow and nutrient cycling. Energy flows consist of food chains and food webs. The nutrient cycles include water, carbon, nitrogen, phosphorus, and sulfur. Various chemical elements resulting from the cycle process are needed to survive living things in the mangrove ecosystem.

Keywords: Biogeochemistry, energy flow, mangrove ecosystems, nutrient cycling

INTRODUCTION

The mangrove ecosystem is also one of the wetland ecosystems (Moudingo et al. 2020). Based on ecological parameters, namely mangrove density mangrove type, it can determine whether an area is suitable or not suitable for ecotourism (Malik et al. 2019 et). Nugroho et al. (2013) stated that mangrove forests are a nutrient contributor to organisms living in and around them. Mangrove species must be able to adapt to salinity conditions (Liang et al. 2008) and also drought during periods of receding seawater. The food chain plays a role in the formation of ecosystem biomass; the food chain explains the relationships within the ecosystem (Yonvitner et al., 2019). With all their potential, mangrove forests are very vulnerable to damage (Takarendehang et al., 2018). Good knowledge and skills will significantly assist in optimizing mangrove ecosystems by maintaining and preserving mangrove forests to benefit the community (Alongi 2002) greatly. The carbon cycle is one of the biogeochemical cycles (Alongi 2020). The characteristics of mangrove habitat factors are different for each region (Poedjirahajoe et al., 2017). Mangrove forest is the richest forest in carbon with a high organic matter content (Donato et al., 2012). The low diversity and vegetation of mangroves can be caused by artificial or unnatural ecosystems (Rudianto et al. 2020). The life cycle of mangroves is determined by water flow, sprouts, depth, and bottom substrate (Saru 2019). Biogeochemistry affects the substrate of mangrove land, which characterizes mangrove habitats (Djamaluddin 2018).

The carbon content in mangrove ecosystems is related to the biogeochemical cycle, namely the carbon cycle (Husalin et al. 2020). Organic matter plays a major role in the biogeochemical cycle (Dittmar et al. 2006). The biogeochemical processes on earth have been developing for three billion years (Hulth et al., 2010). Mangrove forest vegetation has the potential to absorb carbon which is quite large and better than other tropical forest types (Donato et al. 2011). Mangroves have the ability to absorb most of the carbon from the atmosphere stored in stems, leaves, roots, soil which is called carbon stock or carbon sequestration (Abino et al. 2014). Mangrove species density and tree circumference affect the biomass value (Njana et al. 2016). The addition of biomass content affects the addition of carbon content (Chanan 2012). Coastal ecosystems have the potential for carbon absorption; one of the coastal ecosystems is the mangrove (Stringer et al., 2015). With the presence of mangrove ecosystems in Indonesia, Indonesia has great potential for carbon sequestration and storage (Adame et al., 2013). CO_2 reduction and management of carbon sequestration ecosystems can significantly impact global climate change and be used as practical mitigation efforts (Martuti et al., 2018). The nitrogen cycle in the balance in the oceans includes the biogeochemical cycle (Meirinawati 2017). The biogeochemical process of mangroves causes metal and sediment bonds, thereby reducing the transfer of metals to the water (Machado et al., 2002). In these areas, high organic matter content is much more abundant (Setiawan 2013). To determine the stored carbon content, the total tree biomass is calculated by considering the value of the wood density factor, carbon fraction, and biomass expansion (Senoaji and Hidayat 2016). The mangrove ecosystem has service providers (utilization of wood, crabs, and fish), regulatory services (breakwater and prevention of seawater intrusion, cultural services (mangrove ecotourism) with a very high total economic value (Idrus 2017).

The energy flow in mangrove ecosystems includes food chains and food webs involving organic matter (Karimah 2017). Manengki (2010) states that the content of organic matter in sediments in areas with river estuaries tends to be higher due to input from upstream (upstream) land (Sari et al. 2014). Various series of ecological researches on mangrove forests are needed to ensure the ecological function and sustainability of mangrove ecosystem production, ecological data as basic data for mangrove resource management (Julaikha and Sumiyati 2017). In some mangrove ecosystems, there are still those containing heavy metals Cu and Hg that exceed the threshold value (Ernawati et al., 2018). According to the mangrove tourism index, biophysical mangrove ecosystems can be managed (Prihadi et al., 2018). The conversion of mangrove land to other lands, such as agriculture, can damage the mangrove land; mangrove land improvement requires a long time, and costs are high (Putra 2014). Anthropogenic activities that cause mangrove forest degradation are agriculture, plantation, fishery, industry, logging, mining, settlements, and salt ponds (Eddy et al., 2015). The location of mangroves affects the types of mangroves that grow, for example, namely; *Avicennia,* which usually grows in mangrove areas directly facing the open sea; the substrate that is getting muddy and thicker usually has a high genus frequency value (Sunarni et al. 2019). Mangrove fruit is currently increasing food security (Pardede 2013). Several environmental parameters can determine the growth and viability of mangroves; these parameters include freshwater supply and salinity (Sunarto 2008). The carbon cycle is related to carbon sequestration in organic matter (vegetation) and carbon storage (carbon burial) in sediments and soil (Wen Qiu et al., 2011). In the carbon cycle or mangrove biogeochemistry, carbon absorption occurs by the mangrove ecosystem and is stored in the soil (Wang et al. 2013). The biosphere's living and non-living components are related to the biogeochemical cycle (Nasprianto et al., 2016). The biogeochemical cycle can also be associated with the cycles of mercury and other materials in the sea; this cycle affects the resistance of organisms (Budiyanto 2012). The aim of this review was to determine the process and function of the biogeochemical cycle in the mangrove ecosystem.

ENERGY FLOW IN MANGROVE ECOSYSTEM

Energy flow occurs due to interactions in the ecosystem that cause energy transfer between organisms. The flow of energy in the mangrove ecosystem starts from sunlight energy and other organic materials such as phosphate, nitrogen, and organic carbon that enter the mangrove forest environment. Mangrove trees in the photosynthesis process use the energy of sunlight. After solar energy is used for photosynthesis, mangrove trees produce chemical energy obtained from changing light energy. Chemical energy is stored in mangrove trees, so mangrove trees can be called producers. Furthermore, mangrove tree litter such as twigs, flowers, and mangroves fall into the water. Small particles of litter are eaten by surrounding organisms such as shrimp and other herbivores. There is a transfer of energy from producers to consumers I (primary consumers) in this process. The energy stored by level I consumers is about 10 percent of the producers' energy. The next energy transfer occurs when fish or other carnivorous organisms eat the shrimp. The energy of consumer I move to consumer II, with the amount of energy 10 percent of the energy of level I consumers. If mangrove trees are not eaten by level I consumers, the energy is passed on to detrivores or released from the mangrove ecosystem to other ecosystems such as seawater ecosystems as organic matter. Energy can go out because the ecosystem is open.

There are various kinds of energy flows; examples of energy flow in mangrove ecosystems include food chains and food webs. The energy flow runs due to the interaction between components in the mangrove ecosystem. Plant Mangroves that can exercise control over energy flow are called dominant ecological types, such as *Rhizophora apiculata* (Randongkir et al. 2019). Mangrove trees require the breakdown of energy into nutrients. Litter is influenced by altitude, fertility, climate, density, soil moisture, season, plant base area, plant age, and annual variation. The rate of decomposition in mangroves is influenced by forest type, abundance and herbivorous fauna, temperature microbial activity (Friesen et al. 2018), and weather conditions (Loría-Naranjo et al. 2018). Macrobenthos in the structure of energy flows has an important role due to acting as primary and secondary consumers (Achsan 2019).

The food chain is the transfer of energy that occurs from one organism to another due to the process of eating and being eaten in one direction, which forms a food chain. The number of organisms or populations influences the balance of the food populations in an ecosystem. The reduction of one population will affect the population of other organisms. For example, if the shrimp population decreases, it will reduce the shrimp-eating fish population in the mangrove ecosystem. It will also affect the reduction in the fish-eating bird population. Threatening one organism can cause other organisms to be endangered. The food chain in the mangrove ecosystem is divided into 2 types, namely the direct food chain and the detritus food chain. The direct food chain cycle includes mangrove tree litter in the form of flowers, leaves, or twigs falling into the water. Then the litter falls into the water, is carried by the water currents, and is eaten by level I consumers, shrimp, and small fish in coral reefs. Consumer I is preyed on by level II consumers such as fish-eating birds and big fish. When level II consumers die, the decomposer breaks them down into organic compounds, which mangrove trees or plants reuse. The detritus chain is an indirect food chain. One difference from the direct food chain is that in the number of organisms involved, there are more organisms involved in the indirect food chain than in the direct food chain. The detritus food chain cycle begins with mangrove litter falling into the water being broken down by the detritivore. The detritivores are eaten by aquatic organisms such as mollusks, algae, and crabs (crustaceans). Level I consumers are then eaten by level II consumers, namely protozoa. Level II consumers are eaten by level III consumers, amphipods. Then these organisms, such as amphipods, are eaten by small fish, which act as consumers IV. Consumer IV is preyed on by large fish and seabirds belonging to consumer V. Consumer V, or the detritivore will break down the last consumer to die again to produce organic compounds that mangroves can reuse.

Various complex food chains form food webs. In the food web, prey and prey interactions occur, which involve two organisms and multiple types of organisms that eat and eat each other. The food web cycle includes producers eaten by different consumers I. Each consumer I is eaten by a different consumer II. This can give rise to many food chains that interact with each other to form food webs. For example, shrimp and small fish eat litter from mangrove trees. Shrimp are then eaten by other fish, while seabirds eat small fish. According to Kamaruddin (2015), most of the litter or organic material is not directly used by mangrove organisms; litter or organic material will enter the food web in the form of dissolved organic material.

The energy flow process must continue to run to create a balance in the mangrove ecosystem. Energy imbalance can trigger various dangerous things, one of which is global climate change. Mangrove forests that carry out photosynthesis and respiration are very beneficial for humans and the environment as a sink for excess carbon in the atmosphere (Purnobasuki 2012). According to (Hazmi 2017), the average yield of organic carbon in leaf litter, leaf, and sediment can be different; the amount of organic carbon in biomass affects the absorption of CO^2 in leaf litter, leaves, and mangrove sediments. The flow of biomass productivity is calculated starting from the biomass detritus that is available every month (Noer 2009). Methane gas in mangrove ecosystems is related to mangrove biogeochemistry; disturbed mangrove ecosystems have the potential to have high methane gas fluxes (Ulumuddin 2019). According to (Hanifah 2019), one of the mangrove forest organisms important in controlling energy flow is decapods. These animals are influenced by the content of organic matter, pH, salinity, and water temperature. The biogeochemical process makes mangrove ecosystems have bonds between metals and sediments to maintain metal movement (Martuti et al., 2019).

NUTRIENT CYCLE

Living and non-living organisms are composed of several materials that originated within the earth. This material forms the basis for inanimate and living organisms, which are elements consisting of chemical compounds. All living things on earth require matter in both organic and inorganic forms. The material will undergo a recycling cycle through water, soil, and air in an ecosystem. This recycling of material is called the biogeochemical cycle, which involves living things and rocks to maintain and stabilize their survival. A cycle is a series of events repeatedly within a certain period. There will be a cycle of substances or materials with similar events or circumstances in the cycle. Cycles can occur over a long or short period. Cycles are formed in both abiotic and biotic environments. At the same time, a nutrient is a substance needed by organisms to grow, develop and live. The nutrient is a substance that plays an important role for organisms because plants use it to support primary productivity (Alongi 2018). Nutrients are needed and essential for an organism. Nutrients participate in forming the body of an organism in a certain ecosystem. Living things require a minimum of 30 to 40 chemical elements from about 92 known elements in order to live and develop. According to Parsons et al. (1984), nutrients are grouped into two, namely macro and micronutrients, macronutrients are needed in large quantities such as C, H, N, P, Mg, and Ca, while micronutrients required in small amounts include Fe, Mn, Cu, Si, Zn, Na, Mo, Cl, V, and Co. Therefore, nutrients are the essential elements for organisms to meet their needs.

The nutrient cycle is a series of circulating substances needed by organisms in an ecosystem repeatedly. The nutrient cycle runs consistently at all times so that the sustainability of an ecosystem can run well. All organisms need both organic and inorganic material to live. Phosphorus is an essential element in the formation of ATP and nucleotides. Nitrogen is a crucial component in the body, making up proteins and nucleic acids. Meanwhile, according to (Karil et al. 2015), the source of nutrients (phosphate) in the waters in the cycle places sediment as one of the sources. The sediment around the mangrove is mixed with the fallen litter and deposited in the sediment. This condition makes the mangrove forest a nutrient contributor to other ecosystems around it (Indrawati et al., 2013). Nitrogen, phosphorus, and silica are nutrients that have an essential role in the growth and development of organisms (Patriquin 1972; Dennison 1987 in Muchtar 2012). The existence of living things in this world depends on the flow of energy and the cycle of matter in the ecosystem. The nutrient cycle is an example of environmental ecosystem services that provide welfare for living things. In the process of the nutrient cycle, organic and inorganic components are mutually related and influence one another. The existence of living things in this world depends on the flow of energy and the cycle of matter in the ecosystem. The nutrient cycle is an example of environmental ecosystem services that provide welfare for living things. In the process of the nutrient cycle, organic and inorganic components are mutually related and influence one another.

Mangroves derive nutrients from inorganic mineral ions and organic matter and nutrient recycling internally through the detrital-based food web (Strauch et al., 2012). Reef et al. (2010) revealed that it is possible for nutrients in coastal waters to come from the land. Macronutrients can be produced from chemical processes that occur in plants. Observation of the content of limiting nutrients can help identify the relationship between nutrient availability and plant growth (Caubey et al., 2007). According to (Syah et al. 2018), mangrove ecosystems have an important role in ecological and economic cycles because they consist of elements such as the accumulation of dissolved phosphorus, nitrogen, primary and secondary production. Mangroves produce nutrients that can nourish marine waters, mangroves help in the rotation of carbon, nitrogen, and sulfur, and mangrove waters are rich in nutrients, both organic and inorganic nutrients. (Ramdani 2015) also suggests the function of mangroves, namely as a source of nutrient production that is useful for fertilizing marine waters. In contrast, there are nutrients such as phosphorus, carbon, nitrogen, potassium, calcium, and magnesium in mangrove leaves. With a high average primary production, mangroves can maintain the sustainability of fish, shellfish, and other populations (Siegers 2015).

Essential nutrient elements are essential and needed by an organism, namely nitrate and phosphate because other elements cannot replace these two elements. Nitrate (NO3) and phosphate (PO4) are nutrients that determine the stability of vegetation growth (Hartoko 2013). Nitrate is a form of the central nitrogen that is in natural waters which comes from ammonium (Mustofa 2015). Phosphate is an essential element second only to nitrogen which can play a critical role in the development and photosynthesis of roots (Supriharyono 2015). The high nutrient content caused by the continuous decay will result in the waters experiencing a too fertile state or often referred to as eutrophication (Rahajeng 2018). Several nutrient cycles occur on earth, including the water cycle, the carbon cycle, the nitrogen cycle, the sulfur cycle, and the phosphorus cycle.

Water cycle

Water is a compound that is very important and necessary for life. Every individual definitely needs water. With water, the circulation process in the body becomes smooth. Water on earth always experiences movement and rotation continuously. According to (Soewarno 2000 in Sallata 2015), water is a natural resource found above and below the earth's surface and as a non-living natural resource. Water above the earth's surface, such as rivers, lakes, oceans, and so on. Meanwhile, water on the surface of the ground is usually called groundwater. Water is needed for the livelihood of many people, even by all living things (Widiyanto et al., 2015). Water is one of the natural resources that can be renewed and has regenerative power, which is always in circulation called the water cycle/hydrological cycle (Sallata 2015).

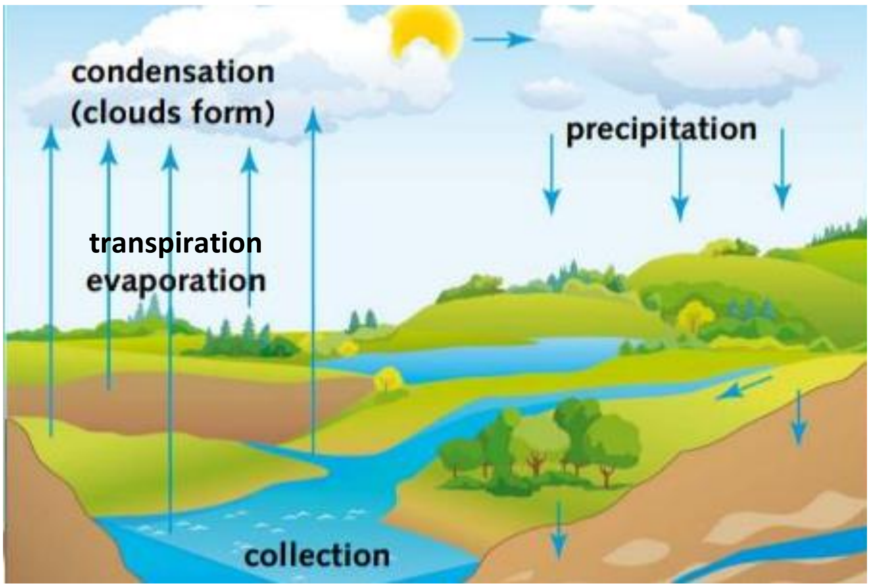

Figure 1. Water cycle (Source: Hutmacher 2013)

The hydrological cycle is water circulation from the atmosphere to the earth then back to the atmosphere and never stops. Water in nature is not static but constantly rotates and moves so that the water available in nature always experiences long-term displacement (Lisnawati 2012). According to (Pynkyawati and Wahadamaputera 2015), the hydrological cycle starts from the evaporation of sea and land water to the air. The hydrological cycle is the movement of seawater into the air, which then falls to the ground again as rain or some other form of precipitation, and finally flows into the sea again. Arrangement cyclically, the event is not simple. First, the cycle can be a short cycle: namely rain that falls on the sea, lake, or river that can immediately flow back to the sea. Second, there is no uniformity of time required by a cycle. It seems the cycle stops in-season dry while the monsoons cycle is running again. Third, the intensity and frequency of the cycle depend on geographical and climatic conditions, which is the result the sun changes its location towards the earth's meridian throughout the year. Fourth, various parts of the cycle can become a complex river, so we can only observe the final part of rain falling above the ground and then find its way back to the sea (Talumepa et al., 2017).

In fact, the availability of water sources in nature is relatively constant. The problem is the changing time of availability and quality because water actually only changes its shape and moves from one place to another. Therefore, it is known that the processes of precipitation (rain), evaporation, and transpiration are the main factors in the occurrence of the hydrological cycle. The heat source from the sun will make surface water mainly in the sea, and lakes/reservoirs will experience evaporation into clouds which by the wind clouds will be carried to the mainland. In their time, the accumulation of these clouds will experience condensation caused by physical processes and altitude to turn into rain. Furthermore, the rain will fall on the earth, which fills the system of lakes, rivers, groundwater, and in the end, it will return to the sea, and there will be a cycle process again (Adi 2018). The process of traveling water on land will form a watershed (DAS) system (Syarifudin 2017).

Mangrove ecosystems play an essential role in the water cycle or hydrological cycle. Mangrove ecosystems provide regulatory/regulatory services in the form of an ecosystem's ability to regulate climate, water and biochemical cycles, soil surface processes, and various biological processes (Dewha 2009 in Anggraini and Marfai 2017). Mangroves are ecosystems that have high productivity for other living things, including fish spawning, nutrient supply and regeneration, water cycles, and carbon storage (Rahmadi et al. 2020). The water cycle process occurs in several stages, including evaporation, transpiration, precipitation, and condensation. The water cycle will continue to move and rotate through the land, water, and air. In mangrove ecosystems, the water cycle begins with the process of transpiration and evaporation from the existing environment, namely the biotic and abiotic environment. Transpiration is a process of evaporation originating from plants (Suparmoko 1997). Meanwhile, evaporation is water from the sea surface that experiences evaporation (Lisnawati 2012). From the evaporation and transpiration process, water in the form of steam will move into the atmosphere and experience condensation in the clouds. The water collected in the clouds will then descend to earth through a process of precipitation to land or return to the sea. Water that falls on land will seep into the ground and flow out to sea. And the transpiration and evaporation process occurs again. This process will continue to repeat itself, forming a cycle. In the water cycle, gravity and sunlight will continuously influence water's movement on the earth's surface (Indriyanto 2006).

Mangroves usually live in muddy and watery places. Mangroves cannot live in dry or waterless ecosystems. (Watson 1928 in Saefurahman 2008) argues that mangrove vegetation cannot live well along with dry coastal areas and does not contain mud or sediment. From the research results in the Cangring Village area, Cantigi District, Indramayu Regency, the substrate types of mangrove sediments are the clay, clay sand, and dusty clay (Darmadi et al. 2012). Therefore, in the mangrove ecosystem, the water cycle can run well. The water cycle can move repeatedly and regularly. According to (Ruitenbeek 1994), mangrove ecosystems have environmental functions, including nutrient supply and regeneration, pollutant recycling, water cycling, and maintaining water quality around the ecosystem. With the water cycle, water availability on earth will not run out; there will only be partial displacement caused by human activity as the inability to maintain this cycle (Smith and Stopp 2004).

Carbon cycle

Carbon is a key element of life and is the fourth most abundant element in the universe after hydrogen (H), helium (He), and oxygen (O). The carbon cycle is the process of exchanging carbon elements between the biosphere, pedosphere, hydrosphere, and atmosphere. The carbon cycle, nitrogen cycle, and water cycle are formed from the sequence of processes that make the earth's key capable supports life - describes the movement of carbon in the biosphere where there are reused and recycled processes. Carbon is an essential element for life on earth as a major component of biological compounds or DNA and a major component of most minerals (Botkin and Keller 2011). This carbon exchange through four main carbon reservoirs: the atmosphere, terrestrial biosphere, oceans, and sediments. The carbon cycle is a biogeochemical cycle that includes chemical, physical, geological, and biological processes and reactions that make up the composition of the natural environment (including the biosphere, hydrosphere, pedosphere, atmosphere, and lithosphere), as well as the cycle of substances and energy that carry the chemical components of the earth in space and time.

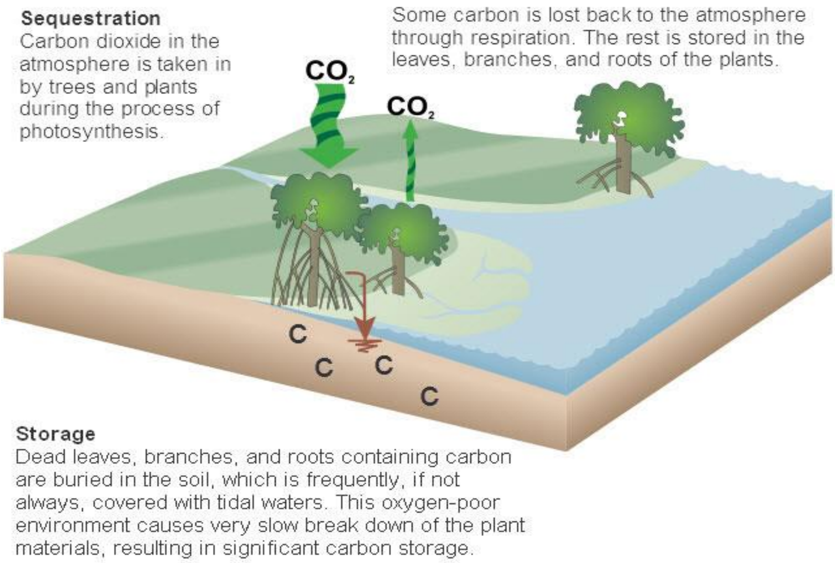

Figure 2. Carbon sequestration and storage in a mangrove wetland (Source: Sutton-Grier et al. 2014)

Forests and seas are natural places on earth that function to absorb CO_2 gas. Carbon dioxide gas is absorbed by growing plants and stored in their wooden stalks. In the oceans, carbon dioxide gas, which is used by phytoplankton for photosynthesis, sinks to the ocean floor along with the feces of living things that eat phytoplankton and other high-level predators. (Daniel and Edward 2011) stated that the ecosystem with the highest carbon absorption capacity is the mangrove ecosystem because it has a high-density value. (Murdiyarso et al. 2015) stated that the ability of mangroves to store carbon stocks makes them an important ecosystem in climate change mitigation efforts. Forest vegetation biomass can be stored above or below the soil surface (Kotowska 2015).

The global carbon cycle can be explained based on the process of displacing and storing carbon in main components. Following are the main components of the carbon cycle according to (Kurniawan 2013): 1) Atmosphere carbon in the Earth's atmosphere can be found in the form of carbon dioxide (CO_2) and methane (CH), both of which are greenhouse gases. Although methane gas has a larger than greenhouse gas effect carbon dioxide, it is in the atmosphere in concentration and a smaller timeframe than carbon dioxide - making carbon dioxide is the leading cause of the greenhouse effect or global warming—the terrestrial biosphere. Carbon in the terrestrial biosphere is found and stored in the form of organic carbon in the form of living and dead living things and stored in the soil in the form of carbon soil. Carbon cycle on the land biosphere, starting from the photosynthesis process in green plants and the process of displacement or transfer through the food chain cycle ends in the decomposition or decomposition of living things; 2) Ocean, the ocean has the largest content of activated carbon in nature, where its storage capacity is second only to the lithosphere. The sea surface stores large amounts of organic carbon, subject to a rapid and direct exchange process with the atmosphere.

Naturally, the release of forest carbon into the atmosphere, or emissions, occurs through various mechanisms such as respiration of living things, decomposition of organic matter, and biomass burning. In addition to the photosynthesis process to convert carbon dioxide (CO_2) into oxygen (O_2), plants also carry out the process of respiration, which releases CO_2. However, this process tends to be insignificant because the CO_2 released can still be reabsorbed during the photosynthesis process. When a forest plant or animal dies, a decomposition process will occur by bacteria and microbes that release CO_2 into the atmosphere. The carbon element is essential in human life, in everyday life, every time the breathing process, humans contribute to the release of carbon in nature in the form of carbon dioxide (CO_2), tree cutting, burning, industrial activities, and motorized vehicles also contribute to the release of carbon in nature (Purnobasuki 2012). The amount of carbon stored for each land varies, depending on the diversity and density of existing plants, soil types, and management methods (Gurung et al., 2015).

The area of mangrove forests in the world is only 0.4% of the world's forest area. However, mangrove forests have a major role as a carbon sink and storage, from more than 4 gigatonnes C/year to 112 gigatonnes C/year. Mangrove forests are forests with the densest carbon content in the tropics. This land stores more than three times the average carbon per hectare of mainland tropical forest (Donato et al., 2011). Indonesia's mangrove forests store five times more carbon per hectare than upland tropical forests (Murdiyarso et al., 2015). Mangroves contribute 10-15% of coastal sediment carbon storage, while global coastal areas only contribute 0.5% (Alongi 2014). Indonesia's mangroves store 3.14 billion metric tons of carbon (PgC) (Murdiyarso et al., 2015). This amount includes one-third of global coastal carbon stocks (Pendleton et al., 2012). The lower surface of Indonesia's mangrove ecosystems stores a large amount of carbon: 78% carbon is stored in the soil, 20% is stored in living trees, roots, or biomass, and 2% is stored in dead or fallen trees (Murdiyarso et al. 2015). Carbon storage in natural forest, swamp forest, and agroforestry, namely 37.2846 tonnes/ha respectively; 39.2875 tonnes/ha; and 36.8416 tonnes/ha. Deposits from these three forests are not much different, while mangrove forests have the largest carbon storage, which is 51.5031 tonnes/ha (Sugirahayu and Rusdiana 2011).

The dynamics of carbon in nature can be explained simply by the carbon cycle. The carbon cycle is a biogeochemical cycle that includes the exchange or transfer of carbon in the biosphere, pedosphere, geosphere, hydrosphere, and Earth's atmosphere. The carbon cycle is actually a complex process, and each process influences one another. According to (Alongi 2012), the carbon cycle has 3 stages: absorption, storage, and expenditure. The absorption process is that mangroves absorb CO_2 in the air and form C6H12O6 (glucose) stored in roots, stems, leaves, flowers, fruit, and seeds. Most carbon storage in plants is found in stems. The process of removing carbon in mangrove plants is caused by several things such as cutting down trees, burning mangrove forests, clearing land, and decomposing dead plant parts by bacteria and fungi.

The process of accumulating carbon (C) in living plant bodies is called the sequestration process (C-sequestration) (Larasati 2012). Thus, measuring the amount of C stored in the living plant body (biomass) inland can describe CO_2 in the atmosphere that plants absorb. Meanwhile, the measurement of C, which is still stored in the dead plant part (necromass), indirectly describes the CO_2 that is not released into the air through combustion. Plants will reduce carbon in the atmosphere through photosynthesis and store it in plant tissues. Until such time as carbon is recycled back into the atmosphere, it occupies one of several carbon pools or pools. All vegetation components, including trees, shrubs, lianas, and epiphytes, are part of the aboveground biomass. Below the soil surface, plant roots also store carbon and the soil itself. On peat soils, the amount of carbon stored may be more significant than the carbon stored above the surface. Carbon storage is more excellent if good soil fertility conditions (Hairiah 2007). Carbon is also stored in debris and biomass-based products such as wood, both surface and stockpiles. Carbon can be stored in a carbon pocket or pool for an extended period or only briefly. The increase in the amount of carbon stored in this carbon pool represents the amount of carbon absorbed from the atmosphere (Sutaryo 2009).

Nitrogen cycle

The biogeochemical cycle describes the process of oxidation and reduction of one inorganic nitrogen compound to another inorganic nitrogen compound. The nitrogen cycle describes changes in the form of nitrogen ions and nitrogen compounds in nature (Reece et al., 2014). Plants use nitrogen to help the photosynthesis process, which is for survival and maintains the food chain in the ecosystem around these plants (Yulma et al. 2018). The primary nitrogen source for plants is free nitrogen gas from the air. Plants cannot utilize nitrogen in the form of elements; nitrogen will undergo several decomposition processes used by plants. Soil microorganisms such as *Rhizobium* will develop symbiosis with plants to help nitrogen availability. Nitrogen is a limiting factor that affects plant growth, including mangroves (Chrisyariati et al. 2014).

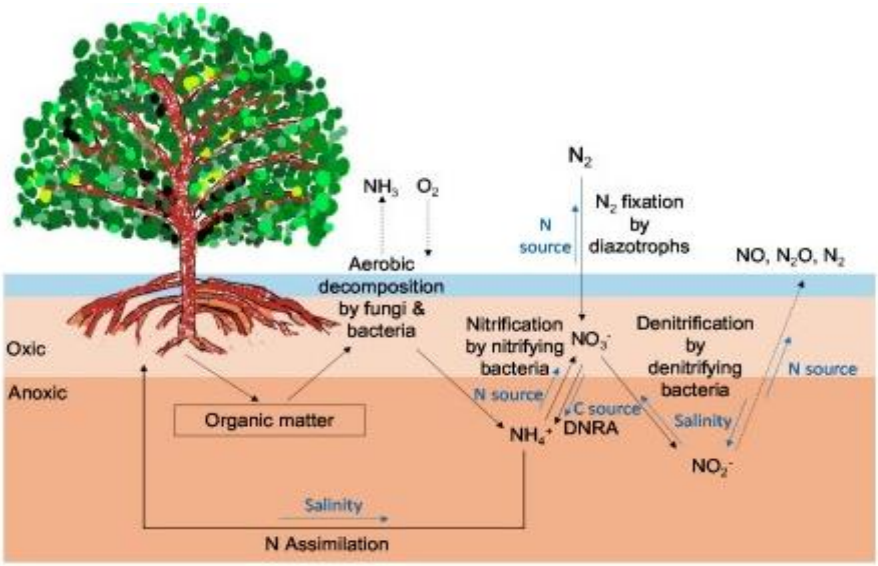

Figure 3. The nitrogen cycle in mangroves (Source: Shiau and Chiu 2020)

Nitrogen stored in soil or sediment is in the form of organic nitrogen (proteins, amino acids) and inorganic nitrogen. Nitrogen in the soil can be lost through volatilization (evaporation), denitrification, and absorption by plants (Oktavia 2006). Nainggolan et al. (2009) stated that nitrogen is an essential nutrient for plants, so there is a lack of nitrogen which causes the plant not to grow optimally. Suharno et al. (2007) stated that the presence of nitrogen is very important, especially about the formation of chlorophyll in plant leaves. The presence of nitrogen in the soil determines vegetation quality (Patti et al., 2013). Nitrogen is needed by plants in large quantities, absorbed by plants in the form of ammonium and nitrate. The nitrogen source is not obtained from aid and minerals. Still, it comes from the weathering of organic matter from the air through nitrogen fixation by microorganisms in symbiosis with plant roots. Another source of nitrogen in the soil is through rainwater and through the addition of artificial fertilizers (Fauzi 2008). The presence of nitrogen in the plant structure is influenced by several factors, especially water availability, nutrients in the soil, especially nitrogen. Three things cause nitrogen loss from the soil: washed with drainage water, evaporation, and plants' absorption.

In the atmosphere, there is ±80% nitrogen in the form of free nitrogen (N2). Some bacteria can absorb nitrogen in the form of N2. The nitrogen bound by the bacteria is converted into ammonia (NH3). This process of forming ammonia is called ammonification. Nitrite bacteria then break down ammonia into nitrite ions (NO_{2-}). Then the nitrite ion is broken down into nitrate ions (NO_{3-}). The process of preparing nitrate compounds from ammonia is called nitrification. New plants can absorb nitrogen in the form of nitrate ions. Nitrate is one of the essential elements that make up protein, nucleic acid, and chlorophyll needed for plant growth. Apart from plants, soil bacteria also utilize nitrate ions to obtain oxygen in the denitrification process (the process of reducing nitrate to nitrogen gas). The nitrification and denitrification processes influence the concentration of ammonium and nitrate compounds in sediments and waters. Nitrogen produced from the denitrification process right is returned to the atmosphere.

A nitrogen cycle process is quite dynamic in the mangrove ecosystem. Nitrogen concentrations in mangrove forest waters are more influenced by mangrove litter decomposition, transfer of nutrients from land, and sediment types (Ramdani et al., 2015). Litter production is an integral part of transferring organic matter from vegetation to the soil (Wahyuni et al., 2016). Analysis of nutrient composition in litter production shows limiting nutrients, and the efficiency of the nutrients used to maintain the nutrient cycle in the mangrove forest ecosystem (Vitousek 1982; Rahajoe et al. 2004). The nitrogen source in the waters comes from the decomposition of dead living things. This is because protein is found in all living things. At the same time, sources caused by human activities are industrial waste and runoff from agricultural areas, fishery activities, and domestic waste (Effendi 2003). Ecological conditions indirectly affect nitrogen content in mangrove ecosystems (Kaseng 2018).

Plants use nitrogen to help the photosynthesis process, which is for survival and maintains the food chain in the ecosystem around these plants (Yulma et al. 2018). The nitrate content in coastal waters is used to measure water fertility because the more optimal the nitrate content of water is, the more abundant marine phytoplankton will be (Wisha et al., 2018). The nitrogen stock in natural mangrove forest sediments is, on average higher than in artificial mangrove forests (Fikri 2017). Natural mangrove forests have denser and older trees and are exposed to tides in the pond area. Dense mangrove forests will result in many tree litter or branches breaking down into sediment. The denser the roots are factors that influence nitrogen storage in sediments. According to Chrisyariati et al. (2014), the older the mangroves, the more nitrogen content will be. Based on the research of Alongi (2011), an increase in N content also occurs along with the increase in tree height and diameter in the mangrove species *Rhizophora* sp. The increase in nitrogen also impacts the development of stem diameter, height, and the number of stands which is better for mangroves (Hermiyanti et al. 2014). The high ammonia content can be caused by the density of the mangrove ecosystem and the influence of agricultural and aquaculture activities resulting from fish feed, which contains a lot of protein from feed residue, fertilization, and metabolic activity of aquatic organisms (Ridwan et al. 2018).

On average, the decomposition process on the mangrove sediment surface is more effective than in the sediment. Surface sediment is an area that is very effective at donating nutrients. Sediment characteristics in mangrove forests can also affect nitrogen stores. The completely decomposed litter can cause an increase in nitrogen stock at depth, but it can also be influenced by the release of organic compounds from the roots. Critical processes in the nitrogen cycle are: but they can also be affected by the release of organic compounds from the roots (Fatih 2008). Fundamental processes of the nitrogen cycle are nitrogen fixation, ammonification, nitrification, assimilation, and denitrification (the process of releasing nitrogen back into the air) (Darjamuni 2003). The nitrogen cycle can be illustrated in Figure 3.

Sulfur cycle

The sulfur cycle occurs among the various biogeochemical cycles in coastal sediments, such as mangrove sediments rich in detritus. From an ecological point of view, mangrove forests can stabilize coastal areas, develop and improve the condition of delta areas, protect coastal areas from waves and storms, protect beaches and rivers as essential sources of the sulfur cycle (Amal et al. 2020). The sulfur cycle is used as a structural and functional role in the amino acid cysteine and methionine and vitamins such as biotin, thiamine, lipoic acid, and coenzyme A (Behera et al. 2014). The existence of sulfur is essential for living things on earth, both plants and animals. Lack of elemental S can cause chlorosis in various plant organs, especially leaves (Yudana 2008). Sulfur is also part of the amino acid Methionine; it is absolutely necessary. The amino acid cysteine also contains sulfur (Siregar et al., 2018). In mangrove ecosystems, sulfur is a factor that affects the percentage of life propagules in mangrove species (Wu et al., 2015). Other functions of the sulfur cycle are to make plant leaves greener, increase the protein and vitamin content in plants, play an essential role in the sugar-turning process.

Sulfurized is the change of sulfur from hydrogen sulfide to sulfur dioxides and then into sulfates and back into hydrogen sulfide again. On earth, sulfur is present in the form of inorganic sulfate. Sulfur in nature is found in various forms. In the soil, sulfur is found in the form of minerals, in the air in the form of sulfur dioxide gas, and in the body of organisms as a building block of protein. Sulfur is reduced by bacteria to sulfides and is sometimes present in the form of sulfur dioxide or hydrogen sulfide (H_2S). Hydrogen sulfide is often deadly to aquatic life and is generally produced from the decomposition dead organic matter. Partially decomposed hydrogen sulfide remains in the soil and is partially released as hydrogen sulfide gas into the air. Hydrogen sulfide gas in the air then combines with oxygen to form sulfur dioxide. Meanwhile, hydrogen sulfide left in the soil with the help of bacteria will be converted into sulfate ions and sulfur oxide compounds. Plants absorb sulfur in the form of sulfate ions ($SO4^-$). The transfer of sulfate occurs through the process of the food chain. All living things die, and their organic components will be broken down by bacteria or decomposers, organisms that feed on dead organisms, and waste products from other organisms. In the sulfur cycle or sulfur cycle, at least two types of processes occur to convert sulfur into other sulfur compounds, namely, through the reaction between sulfur, oxygen, and water and by the microorganism activity of several microorganisms that play a role in the sulfur cycle, including *Desulfomaculum* bacteria and *Desulfibrio* bacteria which will reduce sulfate to sulfide in the form of hydrogen sulfide (H2S). Then H2S is used by anaerobic photoautotrophic bacteria (Chromatium) and releases sulfur and oxygen.

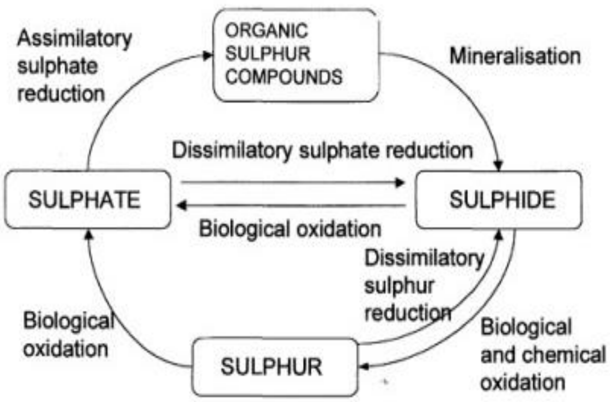

Figure 4. Sulfur cycle in mangroves (Source: Janssen et al. 1999)

Mangrove soils are generally neutral to slightly acidic due to the activity of sulfur-reducing bacteria and the presence of acidic clay sedimentation. The action of sulfur-reducing bacteria is shown by dark, acidic, and foul-smelling soil (Akhrianti et al., 2019). Mangrove sediments are anaerobic and have high levels of organic matter and salinity. Mangrove sediments also act as a source of sulfur (Lopez et al., 2013). So, in order for a nutritional cycle, including the sulfur cycle in a mangrove ecosystem, to remain sound, the quality of the mangrove sediment must be maintained. One of them is by keeping sediment from excessive chemicals. The use of chemicals on the sediment or soil will affect the quality of the sediment because their chemical properties cannot be easily degraded. The direct impact is that H2S or hydrogen sulfide, ammonia, nitrite, nitrate, and carbon compounds can be toxic in shrimp farming systems. This causes the ecological balance of microorganisms in the ponds to be no longer normal (Hastuti 2011). Mangroves are a source of life for marine or coastal fauna, so various fauna live in the mangrove ecosystem. Taqwa (2010) suggests that substrate excavation carried out by mangrove fauna such as crabs, nematodes, Polychaeta, and mudfish is known to have a significant effect on the sulfur cycle in sediments, and sediment has a substantial impact on nutrient cycling and the physical and chemical environment of mangrove forests. The holes made by crabs can increase aeration, facilitate drying of the soil, and support nutrient exchange between sediment and tidal waters (Rizal et al. 2014)

Phosphorus cycle

Phosphorus (P) is a structural and functional component of all organisms, so it is an essential element for all life. Phosphorus is almost undetectable at most sea levels. According to Kolliopoulos et al. (2015), the phosphorus element is not found in free form as an element but in the form of dissolved organic compounds (orthophosphates and polyphosphates) and particulate organic compounds. Phosphorus forms iron and calcium ions complexes in aerobic conditions, soluble and deposited in sediments. Orthophosphates are a form of phosphorus that aquatic plants can directly exploit, while polyphosphates must be reduced to orthophosphate before use. Phosphorus in the form of phosphate is a necessary micronutrient in small amounts but is essential for aquatic organisms. Phosphate in waters naturally comes from weathering rocks and the decomposition of organic matter (Gadd 2010). As reported by Vicente, organic matter in sediments also contributes to the retention of phosphorus by sediment (Vicente et al. 2016). In some marine and estuarine environments, the availability of P is considered a macronutrient that affects the productivity rate of water or is also known as a limiting factor.

According to Hidayat (2001), the phosphorus content in water is characteristic of the waters' fertility. The phosphate content of coastal waters is used to measure water fertility. The more optimal the phosphate content of water is, the more abundant living phytoplankton will be (Takarina et al., 2019). Phosphorus, especially in the form of orthophosphate as a limiting nutrient, has been found in many of them in the eastern Mediterranean Sea. In the form of orthophosphate, phosphorus plays a key role in photosynthesis (primary productivity) (Meirinawatil 2015). Phosphorus comes from various sources, phosphorus from fertilizers and human activities such as waste, erosion, livestock, and paper mills enter rivers, groundwater, and estuaries, causing an increase in anthropogenic P to the sea. Suspended materials may also carry the phosphate absorbed there (Zhuang and Xuelu 2015).

The primary source of phosphorus is in sediments. The sediment source is from decomposed terrestrial sediment carried by river flows towards the sea. The source of phosphorus in mangrove sediments comes from falling mangrove leaves, which are then decomposed into organic material with the help of bacteria. In sediments, these minerals are absorbed by hydrolyzed sediments, especially clay. The increase in phosphorus is proportional to the increase in sediment concentration (Yulma et al., 2018). The high phosphorus content in the sediments is also thought to be due to differences in the number of mangroves standing. This illustrates that the high and low organic matter content is directly affected by the difference in the volume of mangrove leaf litter, which falls into the sediment and finally decomposes into organic matter (Yulma et al., 2018). Sediment is the main storage area in the phosphorus cycle in the ocean. The phosphorus and phosphate content in sediments is influenced by the type of substrate (Supriyantini et al., 2018). P in marine sediments is in the form of particulate matter, bound to metal oxides and hydroxides, estimates of total P in open ocean sediments range from 9.3 x 1010 mol/year to 34x1010 mol/year (Paytan and McLaughlin 2007). The oxygen-containing (oxic) sediments on the surface rich in iron and manganese absorb phosphate and form minerals. In anoxic (oxygen-free) sediments, the phosphate is bound to calcium minerals. The organic P associated with plankton also depends on the redox conditions of the sediments. Phosphorus in sediments can be transferred when degrading organic matter and reducing iron oxides. The phosphate ion concentration in the ocean increases with depth. In response to P-limiting, some phytoplankton species produce enzymes that catalyze the hydrolytic cleavage of phosphate from organic matter. In particular, alkaline phosphates limit P response in many species (Labry et al., 2005).

Most of the phosphorus compounds on earth are stored in rocks. These rocks will experience erosion and free phosphate compounds (PO_4) needed by living things. Phosphorus compounds will be returned to the soil and water by decomposers (decomposing microorganisms). The phosphorus cycle in the environment is relatively simpler when compared to the cycle of other chemicals. Still, this phosphorus cycle has a very important role as an energy carrier in the form of ATP (Adenosine Triphosphate). This cycle of elements is a chemical cycle that produces a precipitate like the calcium cycle. Most phosphorus is present in igneous rock and soil parent material as apatite compounds. Fluoroapatite is one of the known apatite minerals. In the environment, there are no gaseous phosphorus compounds found; in general, the phosphorus elements found in the environment are solid particles. Phosphate is an essential nutrient for the growth of an aquatic organism. However, the high concentration of phosphate in the waters indicates a pollutant. Phosphate compounds generally come from industrial waste, fertilizers, domestic waste, and the decomposition of other organic matter (Makmur et al., 2012). The phosphorus cycle can be illustrated in Figure 5.

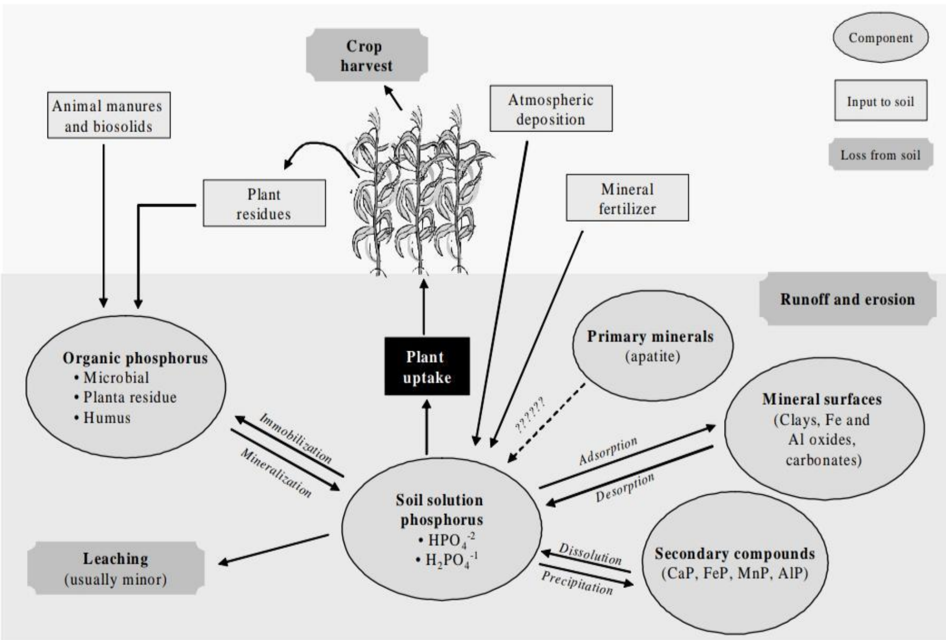

Figure 5. Phosphorus cycle (Source: Vendramini et al. 2007)

Phosphorus is an essential element in life because all living things need phosphorus in the form of ATP (Adenosine Tri Phosphate), a source of energy for cellular metabolism. Phosphorus occurs in nature in the form of the phosphate ion (PO_4^{3-}). The source of phosphate in water comes from various sources. One of them comes from the degradation of organic matter or the weathering of mineral rocks from the land (Maulana et al., 2014). Hutasoit (2014) states that high organic matter content in sediments is directly proportional to the high phosphate content in an ecosystem area. The occurrence of erosion and weathering causes phosphate to be carried to rivers to the sea to form sediments. The input of soil erosion from land carried by the river will be a source of phosphate in the waters. Phosphate compounds play a significant role in the process of eutrophication so that it has the potential to cause blooming algae (explosion of aquatic plant populations such as water hyacinth) if the phosphate content is too high in the water (Ngatia and Taylor 2018). The movement of the earth's base causes phosphate-containing sediments to emerge to the surface.

In the mangrove ecosystem, there is a phosphorus cycle. The presence of phosphorus is important for mangroves. Mangrove growth and structure correlate with the physical and chemical conditions of the soil and the ratio of phosphate, soil water content, sedimentation rate, and soil quality (Hossain and Nuruddin 2016). Phosphate is a limiting factor that affects the growth of mangrove plants (Chrisyariati et al., 2014). Phosphate (PO_4) is one of the major nutrients that determine the stability of vegetation growth, such as mangroves (Reef et al., 2010). It can help the process of photosynthesis, which is for survival, and maintain the food chain in the ecosystem around these plants (Yulma et al., 2018). The condition of mangrove waters which tend to be calm and not much influenced by tides, can cause the phosphate content in the sediment to tend to be high (Supriyantini et al. 2018). The high phosphate content in the mangrove location is influenced by the absence of mangrove vegetation growing at the site so that most of the phosphate is not utilized and settles in the sediment. Muddy coastal waters and river estuary waters contain less phosphate than the waters near mangroves. The mud content is soil material that enters the sea and fresh water and settles because marine energy holds it back. This sediment material contains a small number of macrobenthos which can break down minerals and decompose organic materials into nitrates and phosphates. As a result, the nitrate and phosphate content is less than the waters close to mangroves. The phosphate content in mangrove ecosystems can also be influenced by soil content; there is a relationship between sediment particles (sand, mud, and clay) and phosphate (Amelia et al., 2014).

Nitrogen (N) and phosphorus (P) are critical nutrients that regulate the magnitude and spatial distribution of mangrove forest productivity and structural properties. N transformations are generally slow in mangrove wetlands. N rates vary among mangrove ecotypes and depend on local (nutrient gradients, salinity), regional (geomorphology), and anthropogenic impacts (Kristensen et al., 2017). The use of fertilization experiments under field conditions has advanced understanding of the complex interaction and relative role of N and P availability for mangrove structural development and productivity. The response of ecological processes to nutrient enrichment depends on site characteristics, species composition and dominance, and the nature of nutrient limitation. For example, the resorption of P from senescent tissue by *R. mangle* is under P-limited conditions much higher than that for N. N fertilization does not change this pattern. Still, P fertilization decreases P resorption, whereas N resorption increases: scrub mangrove forests (R. mangle and A. germinans) growing in P limited carbonate sediments always respond to P fertilization, surrounding fringing mangroves (R. mangle) respond primarily to N fertilization. Those exposed to intermediate tidal influence respond to both N and P fertilization as the hydroperiod interacts with nutrient availability (Rivera-Monroy et al., 2017).

P availability within mangrove wetlands is in contrast to N, strongly dependent on the dynamic interactions of P with Fe and S cycling: phosphate (PO_4^{3-}) is readily adsorbed and then retained by Fe (III) oxyhydroxides in near-surface sediments, around crab burrows, and around rhizospheres, then limiting plant production (Nóbrega et al. 2014). However, the adsorbed PO_4^{3-} can be released back to dissolved form and be available again for primary producers when Fe (III) oxyhydroxides are reduced in anoxic sediment. This oxidation-reduction cycle depends on either: the transport of particles between oxic and anoxic zones, typically mediated by crabs when they rework surface and subsurface sediments, or temporal expansion and contraction of oxic zones, primarily due to tidal and seasonal changes in redox conditions.

Interaction between biogeochemical process and flora and fauna in mangrove

The cycle of elements in the mangrove sediment can be influenced by various factors such as land function change, sediment pH, tides, the intensity of sunlight, the life activities of living things, decomposing bacteria. Land-use change can affect the cycle of elements in the mangrove sediment. For example, mangrove land was initially used as aquaculture land, changing its function to mangrove forest or vice versa. Then the land-use change can affect the element cycle. Sediment pH, too high or low, can affect the element cycle. The tides of seawater cause sediment movement, which later affects the element cycle. Sunlight plays a role as the most influential factor in the process of the elemental cycle because sunlight plays a role as a provider of life on this earth. Living things act as life objects on earth influence the element cycle. Bacteria play a role in breaking down all types of inorganic and organic materials. Decomposing bacteria release the phosphorus captured by plants which occur in the elemental cycle.

Sources of sediment in mangrove areas come from land and sea (allochthonous) and from the mangrove area itself (autochtonous) in the form of heaps of leaf, twigs, or dead vegetation and organisms deposited in the mangrove area and contain a lot of organic and mineral (N, P, K, Fe, and

Mg) (Matsui et al. 2015). Mangrove density can affect the level of soil organic matter content. Soil organic carbon content in the mangrove stand habitat varies widely and depends on vegetation type. The diversity of soil organic carbon (SOC) content at soil depth occurs because each vegetation type is different in its vertical root distribution and leaves a distinct footprint on the SOC depth distribution. The amount and dynamics of SOC in the soil are very different in different mangrove species, mainly influenced by tidal gradients, mangrove forest age, biomass, and productivity. The greater the value of the organic matter content, the greater the stored organic carbon content, while the low carbon content in the soil can be due to the low content of organic matter in the soil. And organic matter in the soil is influenced by litter, leaf fall, and existing vegetation. As a manifestation of sediment conditions, the pH and Eh gradients are important factors affecting OC or organic carbon stocks and mobility/absorption of chemical elements. The P and Mg content in leaves increases with increasing pH. Mangrove species show a preference for absorbing certain elements. The organic carbon in the mangrove mud layer is characterized by high aliphatic content, indicating that the soil is not yet moisturized and susceptible to decomposition.

Benthos is an organism that lives on the surface or in the bottom substrate of waters, including plants (phytobenthos) and animals (zoobenthos). Benthos plays several critical roles in waters, such as decomposition and mineralization of organic material, and occupies several trophic levels in the food chain. Macrozoobenthos has a very important role in the nutrient cycle at the bottom of the water. In aquatic ecosystems, macrozoobenthos act as a link in the energy flow and cycle from planktonic algae to high-level consumers (Kaiser et al., 2015). Many benthic live or eat in the mangrove sediments. The vast majority are invertebrates, including crustaceans, polychaetes, sipunculids, mollusks, and fish. The dominant crabs living in mangroves are Brachyuran crabs, which are very dominant because of their speed and ability to move and their way of taking refuge in the mangrove environment (Rivera-Monroy et al. 2017).

The mud and sand substrate were the most preferred habitat for macrozoobenthos (Kumar and Khan 2013). Benthic animals prefer bottom waters with mud, sand, gravel, and waste substrates. Bentos does not like the bottom of the water in the form of rocks, but if the rock bed has high organic material, the habitat will be rich in benthic animals. The type of substrate is related to the oxygen content and availability of nutrients in the sediment. In the sandy substrate, the oxygen content is relatively greater than the fine substrate because, in the sandy substrate, there are air pores that allow for more intensive mixing with the above water. However, nutrients are not much present in the sandy substrate. In contrast to a smooth substrate, oxygen is not the case.

In conclusion, the mangrove ecosystem is a habitat to find food for various marine life, and a biogeochemical process occurs. Biogeochemistry of the organic-inorganic cycle is the process of circulating chemical elements or compounds that flow from the abiotic component to the biotic component and back again to the abiotic component. The cycle of these elements is not only through organisms but also involves chemical reactions in an abiotic environment that occur repeatedly and are not limited. Biogeochemistry plays a role in maintaining environmental stability and maintaining survival on earth. The biogeochemical cycle consists of an energy flow, a series of sequences in which one form of energy is transferred to another form of energy, and a nutrient cycle that describes the use, movement, and recycling of nutrients in the environment. Energy flows consist of food chains and food webs. The nutrient cycle consists of the water, carbon, nitrogen, phosphorus, and sulfur cycles. Various chemical elements resulting from the cycle process are needed to survive both flora and fauna in the mangrove ecosystem. The presence of organic matter in the mangrove environment, especially in the mangrove sediments, affects the elements of the nutrient cycle, movement, and recycling of nutrients in the environment. There is an influence from the presence of vegetation and fauna on mangrove sediments. Vegetation and litter are sources of organic matter in mangrove sediments. Benthos plays a role in the decomposition and mineralization of organic material in mangrove sediments.

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