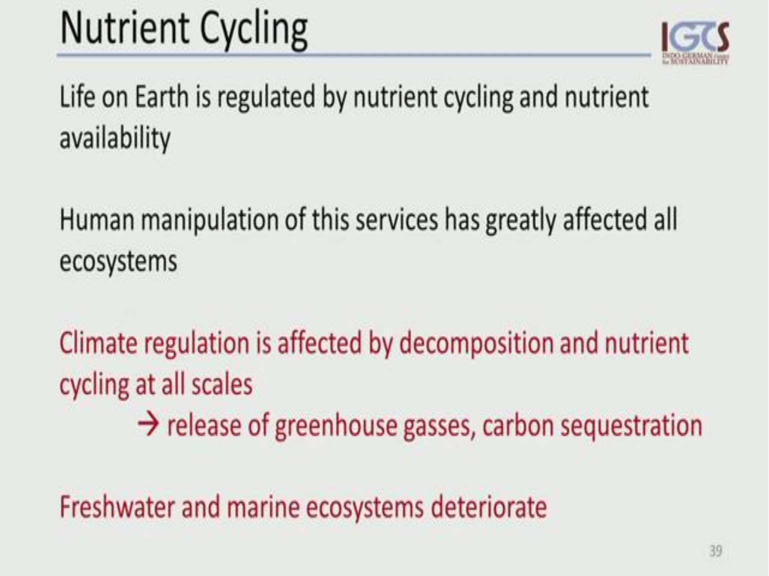
Sustainable River Basin Management
Dr. Franziska Steinbruch
Department of Civil Engineering
Indian Institute of Technology, Madras

Module – 03
Lecture - 14
Part – 04

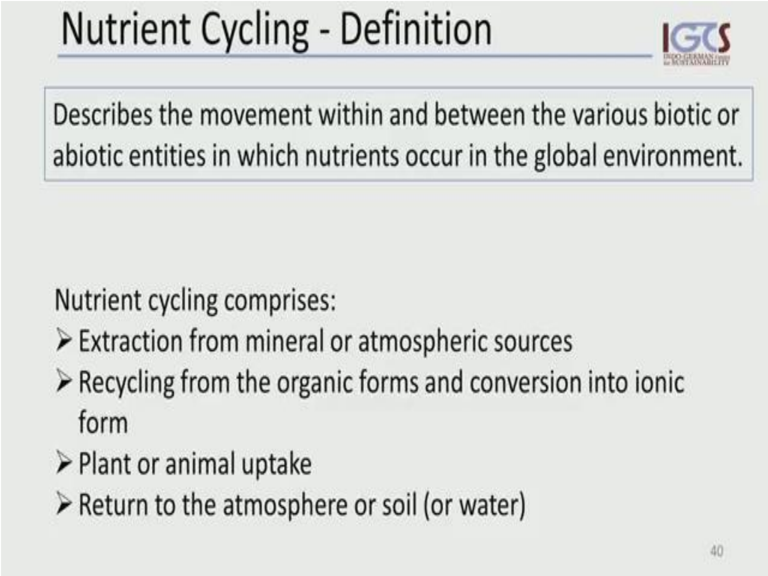
Welcome everybody to Sustainable River Basin Management, part four of module two-two. Today, we will be speaking about nutrient cycles and specifically, in the context of our planetary systems, boundaries. So, we kept what we have been talking about this earlier.

(Refer Slide Time: 00:35)



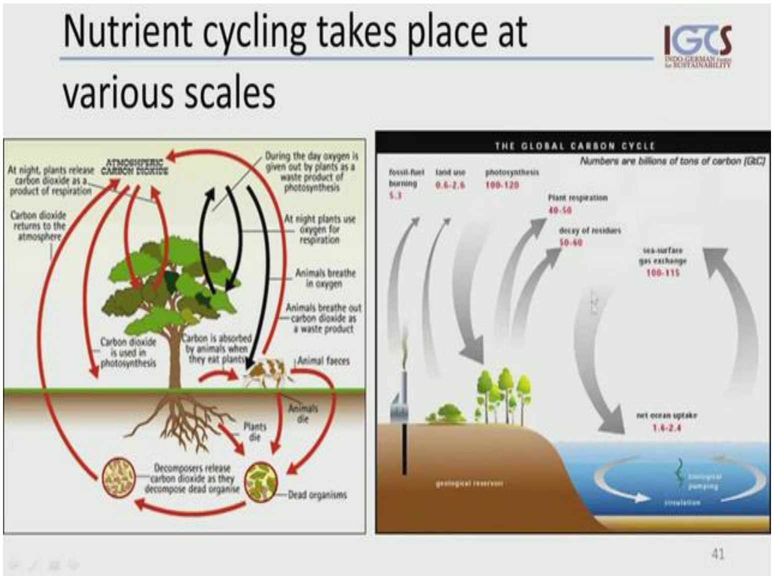
Let us start with nutrient cycling. What we mean by this? It is, life on earth is regulated by nutrient cycling and nutrient availability. Human manipulation of this has greatly affected all of our ecosystems. The climate regulation is affected by the decomposition and nutrient cycling at all scales and this is linked to the release of greenhouse gasses and to carbon sequestration and it has led to the deterioration of our fresh water and marine ecosystems.

(Refer Slide Time: 01:25)



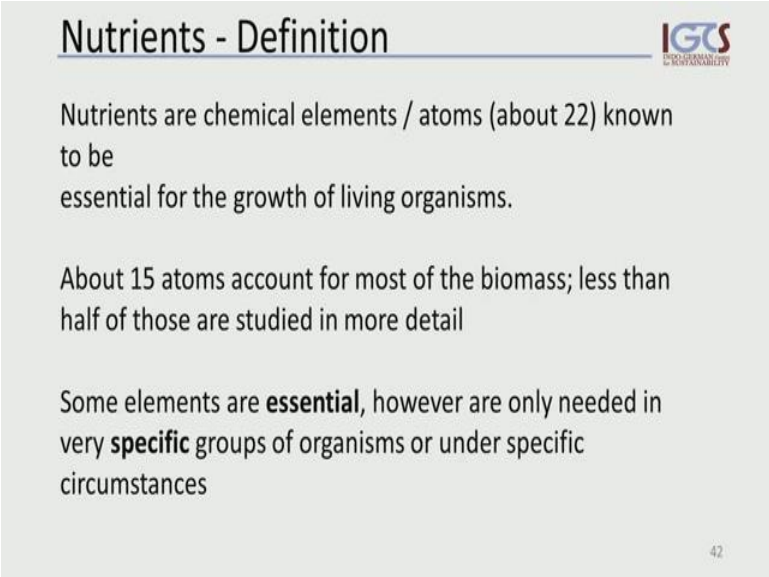
Let us define nutrient cycling first of all. It describes the movement within and between the various biotic and abiotic entities in which nutrients occur in the global environment. So, nutrient cycling comprises of the following. It comprises the extraction from mineral to atmospheric sources. It comprises the recycling from the organic forms and conversion into ionic forms. It comprises the plant or animal uptake and it comprises the return to the atmosphere, the soil or the water.

(Refer Slide Time: 02:10)



Now, important again, nutrient cycling takes place at various scales and as example here, the case of a plant and the processes that takes place around the plant. First of all, between the atmosphere, the plant and the wood parts, the soils, the soil and the above surface, part of the plant and the atmosphere again and the global cycles, that we observe. Just like in our water cycles, we also have a nutrient cycle that takes place at a global scale that takes place between the ocean mess, that takes place on our terrestrial parts and it connects all of these nature length surface through our atmosphere.

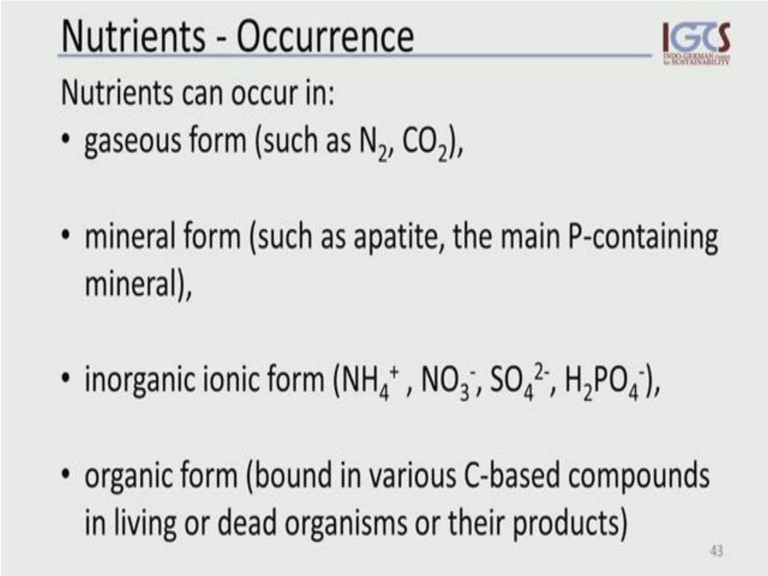
(Refer Slide Time: 03:16)



We have talked about nutrients cycling, let us look in to the nutrients as such. Nutrients are chemical elements or atoms and there are only about 22 of 10, which we know our essential for the growth of living organisms and those are the nutrients and out of those about 15 elements or atoms account for most of the biomass. So, less than half of those are properly understood and studied in detail.

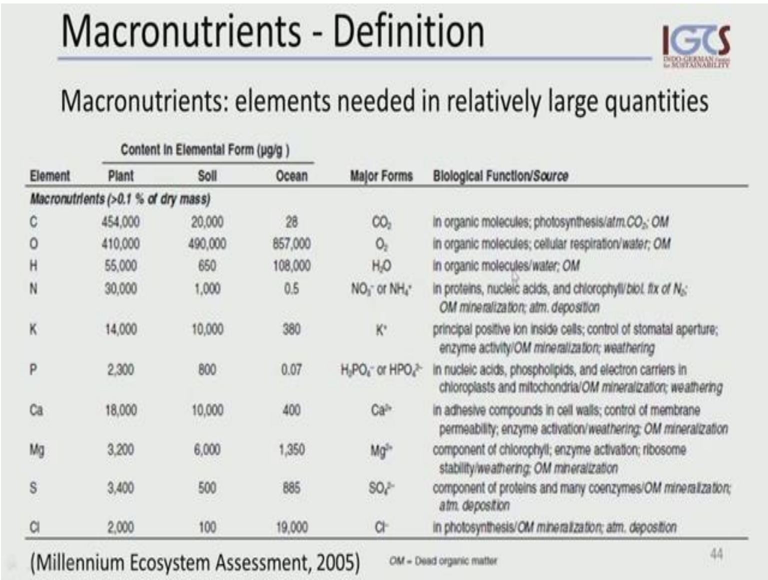
We also know, that some of these elements are essential for life, but some of them may only be needed in very specific groups of organisms, not to all of us or all of the plants and they may also only be required under very specific circumstances. So, this make it already quite selective and although are essential.

(Refer Slide Time: 04:29)



Now, nutrients occur in the form of gases, for instance, nitrogen or carbon dioxide, the most known may be. They occur in mineral form. For instance, very important, the phosphate, the phosphorus containing minerals. They also occur in inorganic ionic form, means in solution, for instance, in water. And they occur in organic form, for instance, mostly found in carbon based compounds, in living or dead organism or their byproducts.

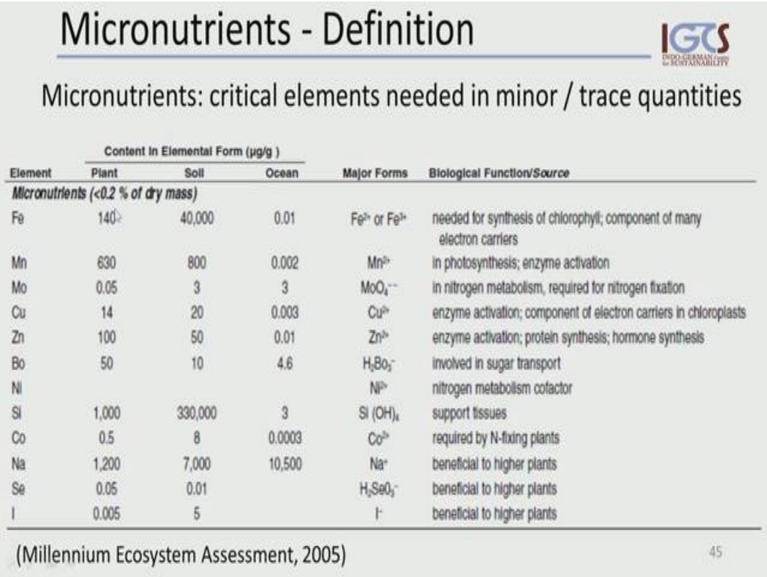
(Refer Slide Time: 05:14)



Element	Content in Elemental Form (μg/g) Plant	Soil	Ocean	Major Forms	Biological Function/*Source*
Macronutrients (>0.1 % of dry mass)					
C	454,000	20,000	28	CO_2	in organic molecules; photosynthesis/*atm.* CO_2; *OM*
O	410,000	490,000	857,000	O_2	in organic molecules; cellular respiration/*water; OM*
H	55,000	650	108,000	H_2O	in organic molecules/*water; OM*
N	30,000	1,000	0.5	NO_3^- or NH_4^+	in proteins, nucleic acids, and chlorophyll/*biol. fix of* N_2; *OM mineralization; atm. deposition*
K	14,000	10,000	380	K^+	principal positive ion inside cells; control of stomatal aperture; enzyme activity/*OM mineralization; weathering*
P	2,300	800	0.07	$H_2PO_4^-$ or HPO_4^{2-}	in nucleic acids, phospholipids, and electron carriers in chloroplasts and mitochondria/*OM mineralization; weathering*
Ca	18,000	10,000	400	Ca^{2+}	in adhesive compounds in cell walls; control of membrane permeability; enzyme activation/*weathering; OM mineralization*
Mg	3,200	6,000	1,350	Mg^{2+}	component of chlorophyll; enzyme activation; ribosome stability/*weathering; OM mineralization*
S	3,400	500	885	SO_4^{2-}	component of proteins and many coenzymes/*OM mineralization; atm. deposition*
Cl	2,000	100	19,000	Cl^-	in photosynthesis/*OM mineralization; atm. deposition*

When we talk about nutrients, we differentiate, differentiate between two types, one is the macronutrients. Those are elements, which are needed by organisms in relatively large quantities. And examples here of these macronutrients are listed, they are listed here and carbon, oxygen, hydrogen, nitrogen, etcetera, the occurrence in plant material and soils, in oceans in which form a chemical formed there and most often occurring. And then, we have here a brief list of biological functions of these micronutrients. So, they are, those processes are better understood.

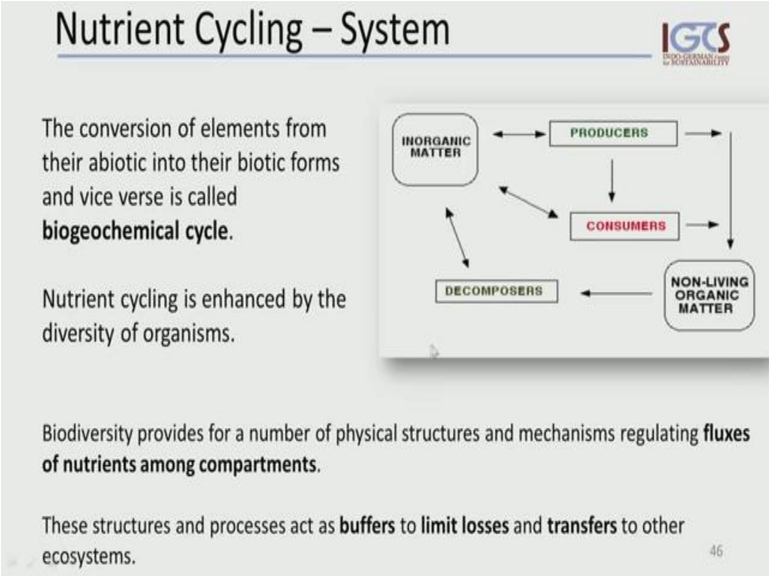
(Refer Slide Time: 06:14)



Element	Content in Elemental Form (μg/g) Plant	Soil	Ocean	Major Forms	Biological Function/*Source*
Micronutrients (<0.2 % of dry mass)					
Fe	140	40,000	0.01	Fe^{2+} or Fe^{3+}	needed for synthesis of chlorophyll; component of many electron carriers
Mn	630	800	0.002	Mn^{2+}	in photosynthesis; enzyme activation
Mo	0.05	3	3	MoO_4^{--}	in nitrogen metabolism, required for nitrogen fixation
Cu	14	20	0.003	Cu^{2+}	enzyme activation; component of electron carriers in chloroplasts
Zn	100	50	0.01	Zn^{2+}	enzyme activation; protein synthesis; hormone synthesis
Bo	50	10	4.6	$H_2Bo_3^-$	involved in sugar transport
Ni				Ni^{2+}	nitrogen metabolism cofactor
Si	1,000	330,000	3	$Si(OH)_4$	support tissues
Co	0.5	8	0.0003	Co^{2+}	required by N-fixing plants
Na	1,200	7,000	10,500	Na^+	beneficial to higher plants
Se	0.05	0.01		$H_2Se0_3^-$	beneficial to higher plants
I	0.005	5		I^-	beneficial to higher plants

Then, we have on the other hand the micronutrients, which are critical elements and which are needed in minor or trace quantities. What is important is that they are critical. Those elements may, are limiting, availability of certain or course, survival of species. So, they are although micro, they are critical and essential elements. A list here of these micro nutrients, one of them is iron, manganese, but also saline, a saline or copper or micronutrients of which we know some of the biological function. In many cases, those are, play some whole catalyst in enzyme activation in very specific processes within organisms. They occur usually in minor amounts in the aquatic form and are accumulated in either in soil or in plant material.

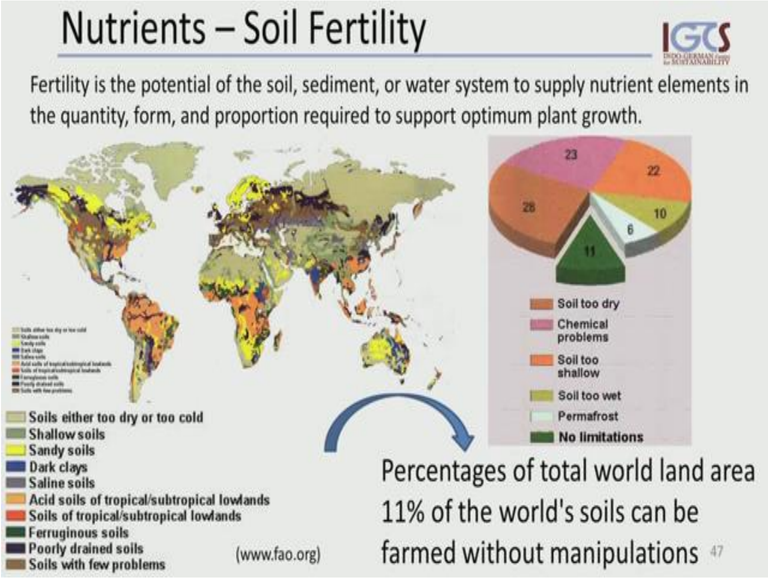
(Refer Slide Time: 07:40)



Now, let us look into the nutrient cycling as a system. So, what we mean by cycling is that we mean, a conversation of a, conversion, sorry, a conversion of elements from a non-biotic into a biotic form or vice versa and that process is usually called biogeochemical cycle. You are probably familiar with this cycle, inorganic matter, a producer was an inter link to each other. We have a consumer, which produces inorganic matter and produces dead matter or produces left over that will be used by a decomposer and again move back into an inorganic matter. So, we have several cycles, which depend on each other, but we have one, which is a consumer, which essentially lifts off what comes from the other storage compartments.

Now, the nutrient cycling is enhanced by the biodiversity and the diversity of organisms. Why that? The biodiversity provides for a number of physical structures and mechanisms, which regulate those fluxes, indicated by these arrows here, of nutrients among those compartments. So, the more richer the biodiversity here is, the more efficient is connection can work. So, these structures and processes act as buffers in between and they limit losses and transfers to other ecosystems. So, this is a very important connection.

(Refer Slide Time: 09:51)

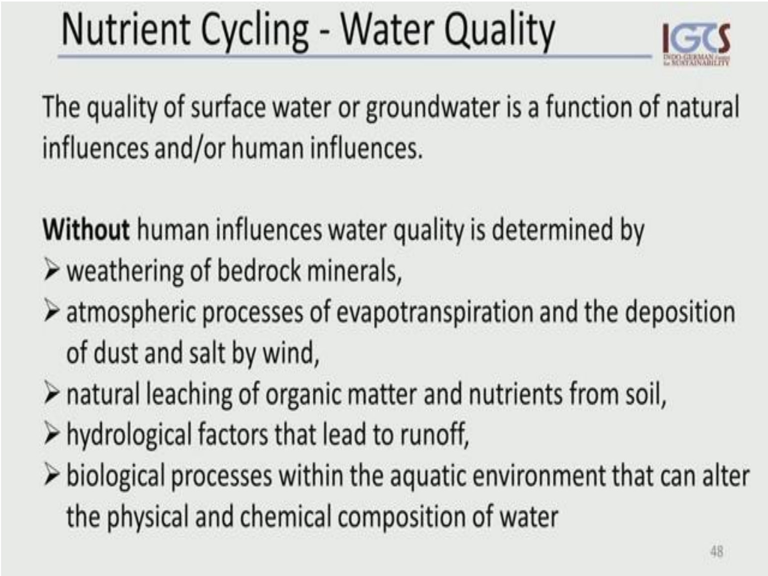


Now, important for us, not just as the building material for a biological life, nutrients are also important as in determining soil fertility, is very important for agriculture purposes for human needs. So, fertility is the potential of the soil or sediment or water systems to supply nutrient elements in the quantity in the form and proportion required to support optimum plant growth. So, there are several factors playing the role here not just the amount is important. We have to look into in which form, in which chemical form this nutrient occurs and the proportion of one nutrient in relation to another element or element groups are way of important and limit the availability of that particular nutrient.

Now, this is a map showing us soil fertility. This is an FAO map and what we can see, should not see all the details, but what you see mostly are reddish, orange and yellow colors. Those are acidic soils of tropical lowlands and sandy soils dominating a pass of that and we have some brownish areas where we have classified as soils, was very few problems in terms of soil fertility.

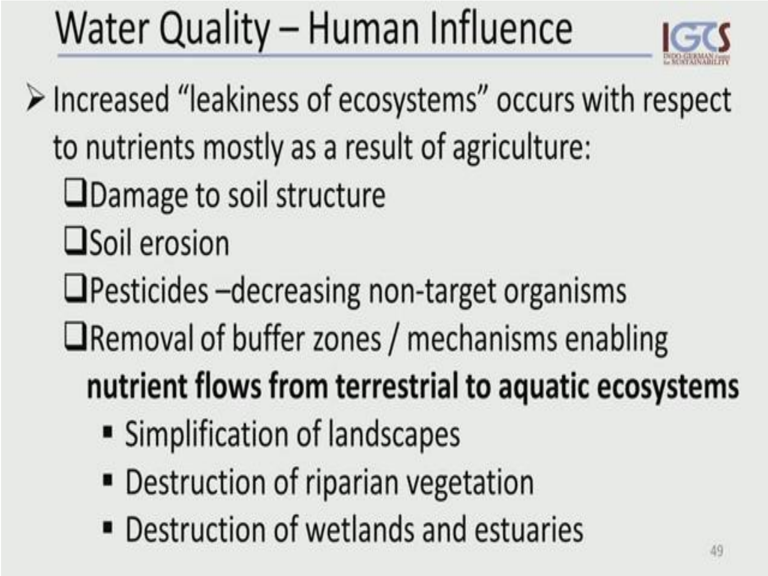
Now, if we take this information or into and group it into another statistical form, this shows us the percentage of total land area, then we see that we have only 11 percent of the area. This screen part of the pie, which could be used for, which has good soil fertility, which is balanced from the point of nutrient availability. And all the other soils need, have limitations and or need, would need additional intervention to improve some, may be to time, they need irrigation, irrigation, come additional issues. There may be problems of nutrient availability. The soils may be too shallow, too wet and so on. So, this is quite important to realize, that only 11 percent out of the total land mass actually has good soils for farming purposes.

(Refer Slide Time: 13:03)



Now, we have looked at soils, now important to ask, want to talk about the river system is water quality. Remember, that we said, that water quality is a function of natural influences and human influences. What would be the factors influencing water quality without human influence? That would be, essentially, the weathering of bedrocks, which contributes minerals, nutrients to water, the atmospheric processes of, for instance, evapotranspiration and the deposition of dust and salt by wind would influence the water quality, could be a natural leeching of organic matter and nutrients forms soil into water. There could be hydrological factors that lead to specific runoff washing out of the nutrients. There could be biological processes in, within aquatic environment that can change physical and chemical compositions of water. These are the processes without human influences.

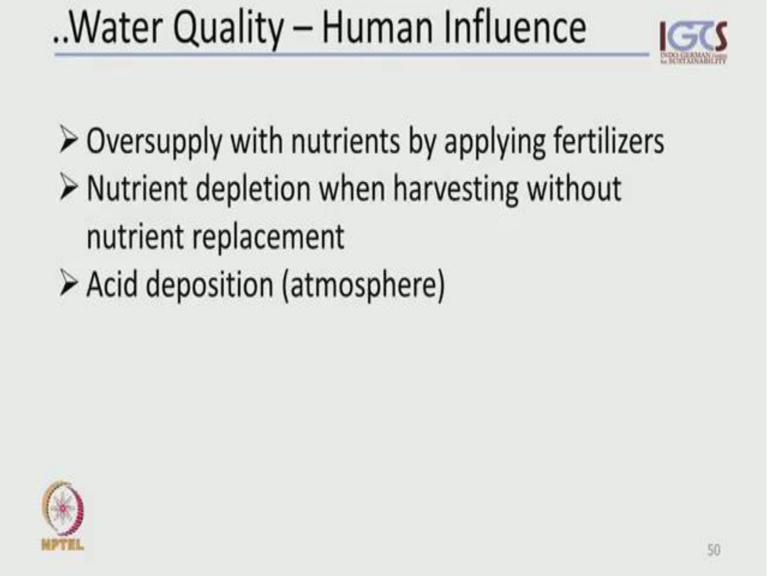
(Refer Slide Time: 14:28)



Now, we know, that we have been influencing and shaping our water bodies for as long as we are on this planet. And what is our impact? We increase, essentially, the leakiness of ecosystems, this respect to nutrients and this mostly in terms of agriculture, farming. We damage the soil structure, we compact soils or we create new, we, we change the layering of soils, we change soil moisture. In that way, we increase the soil erosion. We have been applying pesticides, which decrease also non target organisms. We have been removing our buffer zones and all of them mechanisms that enable now ((Refer Time: 15:25)) to flow from a terrestrial to the aquatic ecosystems. So, we have removed those buffers and in that way we have bridged flows, nutrient flows from terrestrial to aquatic ecosystems.

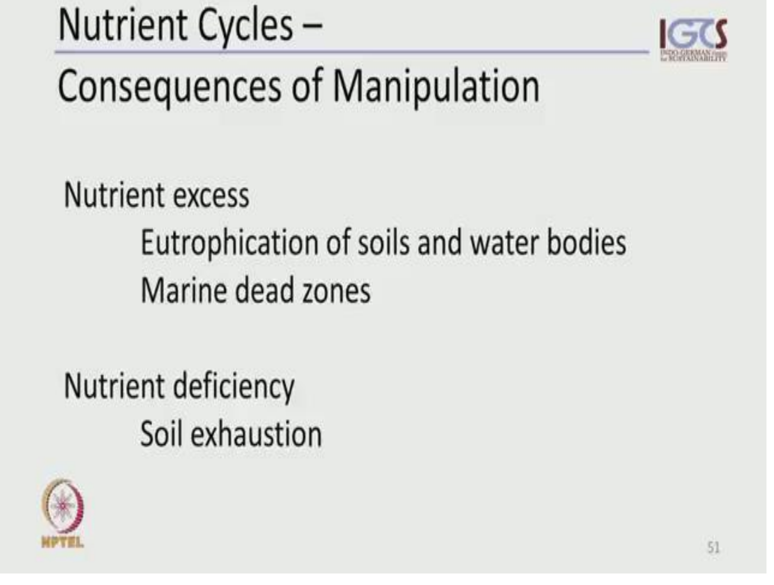
How, what type of buffers are we talking about? We have been simplifying our landscapes by often straightening rivers or by creating shop boundaries between different land use forms, urban, agricultural forests and so on. So, we have removed buffers, for instance, by destroying the riparian vegetation and one of the major buffers that we have also been destroying efficiently are wetlands and estuaries, mangrove zones, for instance.

(Refer Slide Time: 16:25)



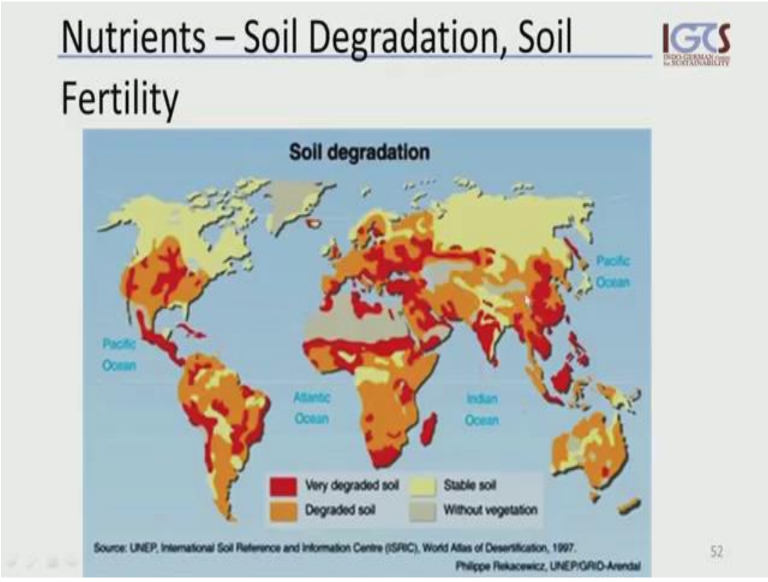
Now, this is not all, we also have been over supplying certain parts of the ecosystems by applying fertilizers. We also have caused, on the other hand, nutrient depletion when we harvest and we produce one and the same monoculture and one piece of land, resort, replacing the nutrients that we taking out. We have caused acid deposition in, through our atmosphere.

(Refer Slide Time: 17:02)



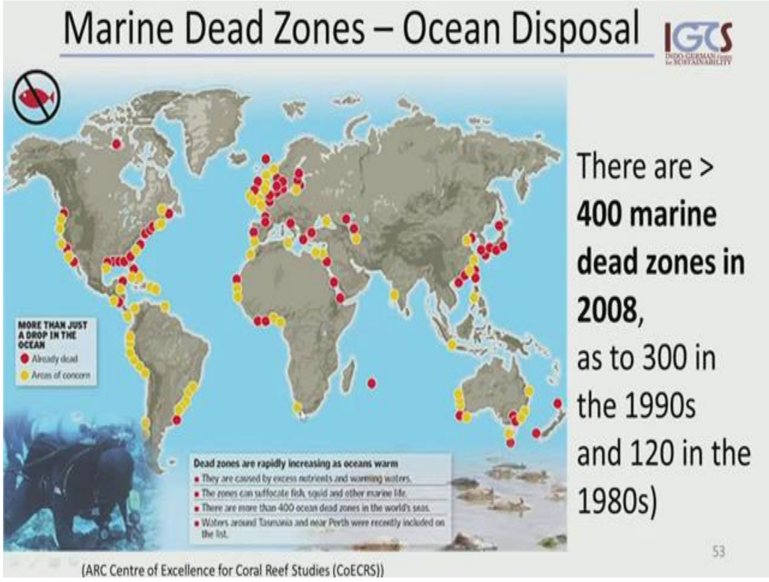
So, there are various consequences of manipulating nutrient cycles. On one hand side, nutrient excess, we have, the result is the eutrophication of soils and water bodies. So, we have transferred nutrients from terrestrial into aquatic ecosystems and one of the major results also are so called marine dead zones. And on the other hand, another extreme we have called nutrient deficiency, we have exhausted our soils.

(Refer Slide Time: 17:46)



Now, let us look into the soil degradation and soil fertility. We have looked into soil fertility from what we have in terms of potentials. And this is now a map showing us the soil degradation. The red colors and orange colors show us very degraded and degraded soils and the grey shows us zones without vegetation and the yellow colors are so called stable soils. So, we see, that there are large parts or would say, most of the parts of our continents characterized by very degraded and degraded soils and we know of this, of the progression of desserts, for instance, and desertification on the increase, and the loss of urban soil in, especially, those transit areas between natural desserts and non desserts.

(Refer Slide Time: 18:59)



Now, this is on land. When we look into our oceans, it is we look into very severe situation also into the so called marine dead zones. This is the result of our usage of the ocean as a, as a waste disposal, a sewage disposal area. We see here red dots and yellow dots, which indicate those marine dead zones. It means, that we do not have any fish production anymore, any productive aquatic life occurring in those areas any more. So, fishery has collapsed in those areas. This is due to an excess of nutrient nodes.

So, what the tendencies are? In the 1980's when first attention came up to this because the fishery industry was hit by losses, only, not only, 120 were identified and this has sharply increased, in, in just 10 years and reach, reached about 400 in 2008 and it is still increasing. So, some of the areas, which are not marked yet as a marine dead are nowadays critical, in critical stage and would be marked here in these some yellow dots here. So, this is a major concern, loss of soil fertility and the dying of our aquatic life in our oceans and we will be talking about this along those lines in our next class.