Sustainable River Basin Management

Dr. Franziska Steinbruch

Department of Civil Engineering

Indian Institute of Technology, Madras

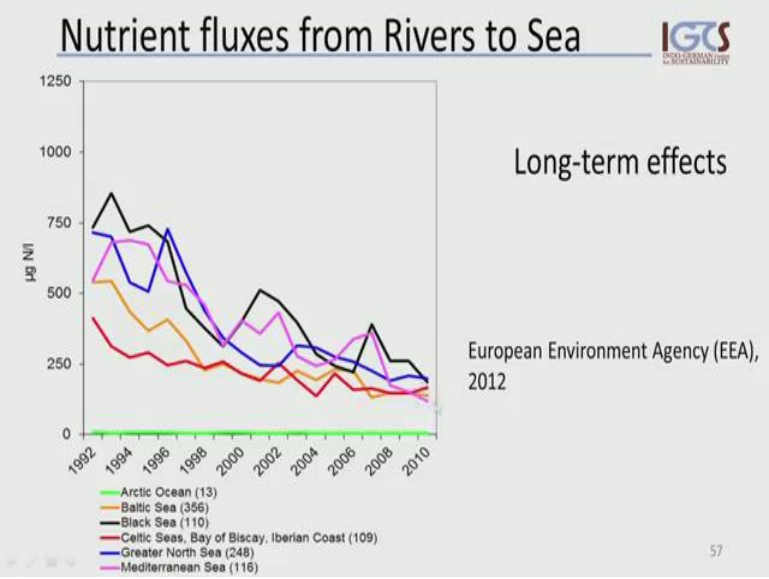
Module – 03

Lecture – 15

Part – 05

Welcome back to Sustainable River Basin Management, Part-five, our last one of module two-two, and today, we will be continuing on Nutrient Cycles and Planetary Systems Boundaries.

(Refer Slide Time: 00:56)



We have last time talked about soil fertility and the effect of leeching of nutrients from the terrestrial to the aquatic system, the effect of the marine dead zones. I just want to show you a few other examples of nutrient fluxes from rivers to the sea as to show you the long term effects of it. This is an example from the European environmental agency. It shows us years here and nitrogen loads along here, and the different color lines here are measurements of nutrient fluxes from rivers into the Arctic Ocean, into the Baltic Sea, into the Black Sea, the Celtic Sea, the North Sea and the Mediterranean Sea.

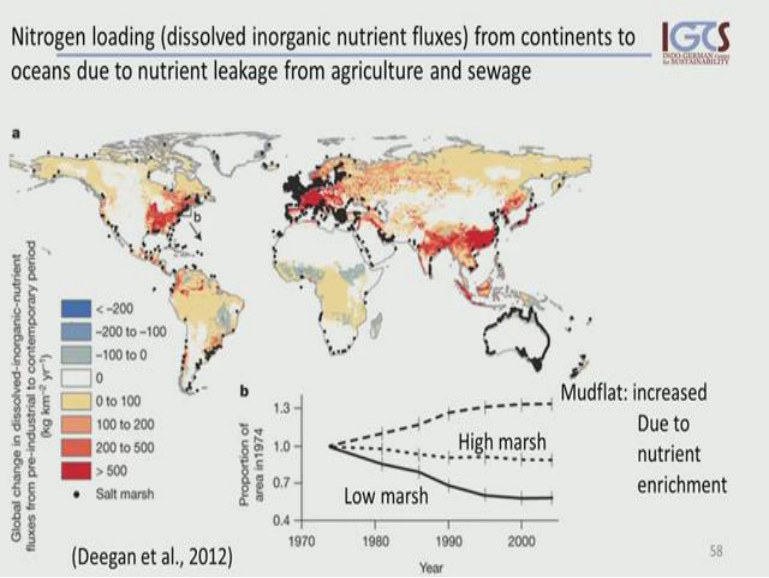
What you can see is, that major efforts have taken place to reduce that nutrient flux from rivers into these seas. It has reduced substantially. We have the Arctic Sea here as sort of

a reference line here. We can switch the, we can measure other, the nutrient fluxes in other parts of the world. But we also see is, that there are quite some ups and downs in these amounts of nutrient loads and very often we can link those to specific events like nature disasters or major event, political changes or major implementation of enforcement of laws and regulations.

So, we can link this, although we do not have countries named here, but we know, which countries are bordering or these seas or which rivers pass ending, draining into these seas pass through which countries. So, this is quiet interesting to see that. Although there are major efforts being done on reducing those loads, still they are substantial and still they are very susceptible to specific non-action or actions in certain parts of the river system and still being detectable in those seas.

So, there is a long term effect in this, notable from an overall perspective, what individuals can do, what politics can do and how long lasting also political interventions and scientific intervention have to be to produce measurable effects.

(Refer Slide Time: 03:51)



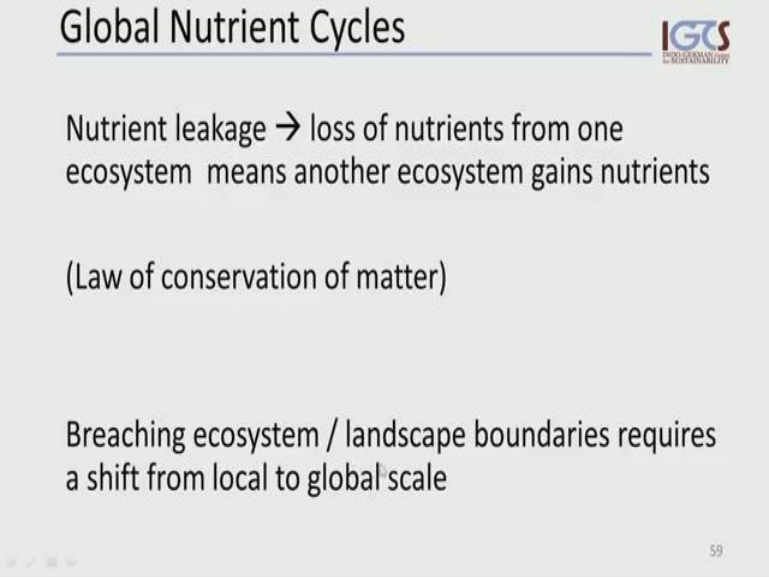
Another example here, which gives us a good sense of the nitrogen load from continents to oceans as a nutrient leakage from agriculture and from sewage. We have here a global map, which shows us on one hand in colors, the global change in dissolved inorganic nutrients. We have blue here, a negative reduction, and in red the extreme increase of nutrient loads. You can see, which parts of, at our terrestrial zones are major, have seen these major increases. Also, Europe has done, put a lot of effort into changing, enforcing

changes in the agriculture sector, still it is a major, there is a major increase in nutrient loads, same in the Asian region here.

Now, what is a good indicator for sewage and nutrient leakage from the continents to the ocean are mudflats. Mudflats are the borders on, along the ((Refer Time: 05:34)) of our between the continent, our continents and the ocean. Mudflat numbers or the black dots here have increased substantially over the years.

Although we know, that our sewage treatment facilities are in place and we do, try to do our best to capture and treat water before it is been released into a, an ocean or into a stream, still it is been detectable and on the increase. Whereas, our more natural marsh systems have been substantially decreasing, and being, are still on the decrease. So, those are measurable indicators for these nutrient loads, which in itself can build up an index towards monitoring our planetary boundaries.

(Refer Slide Time: 06:44)



Now, let us go, move out of this basics and look into our global nutrients cycles. Now, our nutrient leakage means, as such a leakage is not a loss of nutrients from one ecosystem, it is a cycle. What is been removed from one ecosystem means, that it is been moved out of one ecosystem into another ecosystem. So, one is a losing ecosystem on a storage compartment and another is gaining nutrients. It is useful for that ecosystem or not is not been said here.

So, the law of conservation of matter applies also when we talk about nutrients and nutrient cycles. So, nothing will simply disappear somewhere, it always appear in

another part of our cycle in another form and eventually, come back to us. So, what we have been doing is breaching ecosystems and what the result of this is, that we have to look not only at managing our landscapes, but to look into what happens at the transitions at the fringes or landscape boundaries.

We also have to look into the matter as not something that can be influenced at a local scale, but it has a global impact. So, we have to, we can do our intervention at local scale and still globally ((Refer Time: 08:39)) picked up or we may change something locally and still it will have its influence at different locations globally due to the linkage in cycles.

(Refer Slide Time: 08:57)

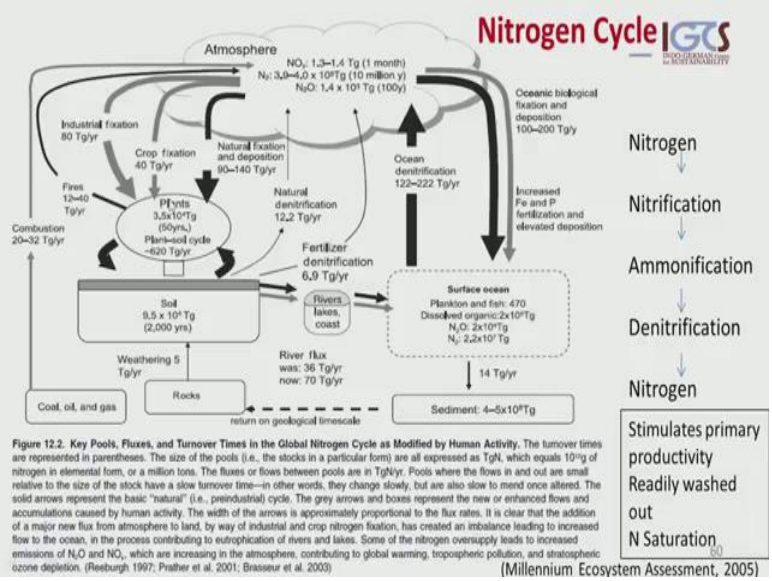


Figure 12.2. Key Pools, Fluxes, and Turnover Times in the Global Nitrogen Cycle as Modified by Human Activity. The turnover times are represented in parentheses. The size of the pools (i.e., the stocks in a particular form) are all expressed as TgN, which equals 10^{12}g of nitrogen in elemental form, or a million tons. The fluxes or flows between pools are in TgN/yr. Pools where the flows in and out are small relative to the size of the stock have a slow turnover time—in other words, they change slowly, but are also slow to mend once altered. The solid arrows represent the basic "natural" (i.e., preindustrial) cycle. The grey arrows and boxes represent the new or enhanced flows and accumulations caused by human activity. The width of the arrows is approximately proportional to the flux rates. It is clear that the addition of a major new flux from atmosphere to land, by way of industrial and crop nitrogen fixation, has created an imbalance leading to increased flow to the ocean, in the process contributing to eutrophication of rivers and lakes. Some of the nitrogen oversupply leads to increased emissions of N_2O and NO_y, which are increasing in the atmosphere, contributing to global warming, tropospheric pollution, and stratospheric ozone depletion. (Reeburgh 1997; Prather et al. 2001; Brasseur et al. 2003)

(Millennium Ecosystem Assessment, 2005)

Now, let us look into the major, the most important cycles and let us start with the nitrogen cycle here. I have loaded those complete figures out of this report here, which I really recommend you to read in detail to understand it properly, the millennium ecosystem assessment of 2005.

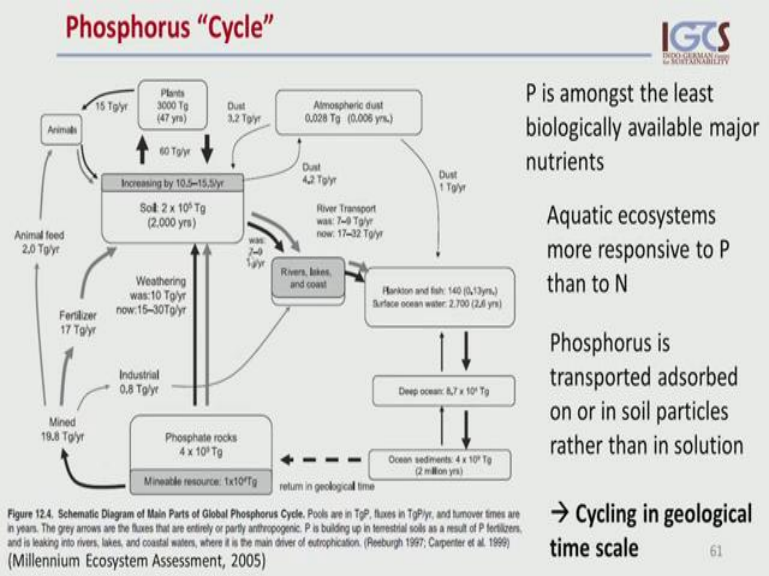
What we see here is, are the stage compartments, those boxes here, different boxes and the division into our oceanic part, the ocean water part, the river systems here and our terrestrial part above surface and in rock soils or geological information, and we have our atmosphere here. And all of the other images, which I am going to show you, it is always be the same concept. And the black arrows are indicating our fluxes, our flows between compartments and the black arrows will show us what the natural system has been and looks like without human intervention.

So, what we see in the case of the nitrogen cycle are essentially two major cycles, one involving the ocean and one involving our terrestrial surface, both essentially linked through the atmosphere and in minor quantities through our river systems.

Why nitrogen is so important? It simulates primary productivity and it is easily been washed out of soil systems or from soil surfaces, will not be taking, taken up and be washed out or fixed in, washed into the ground water systems and reaching the ground water tables. So, the processes which take place is, that nitrogen changes from its atmospheric, from its gaseous form. So, nitrification and ammonification, denitrification process back into nitrogen.

So, they are microorganisms and plants adapted to changing the stage in which nitrogen occurs. They are microbes, microorganisms and plants, able to a take up nitrogen from a gaseous environment, from an aquatic environment and fix it or put it into a solid state in plant course or in non-biotic matter. So, in theory, as we increase, we could increase our plant activity in this way.

(Refer Slide Time: 12:49)



So, a different cycle on this is, completely different cycle to, compared to this nitrogen cycle, where we have microorganisms adjusted to working and removing the nitrogen from, from, current state is the phosphorus cycle. We have, again, our ocean compartment here, we have the atmosphere here and we have our terrestrial compartment here. And, what we can see here is, that we essentially have a minor cycle occurring between our terrestrial processes, our terrestrial compartments, which have very little

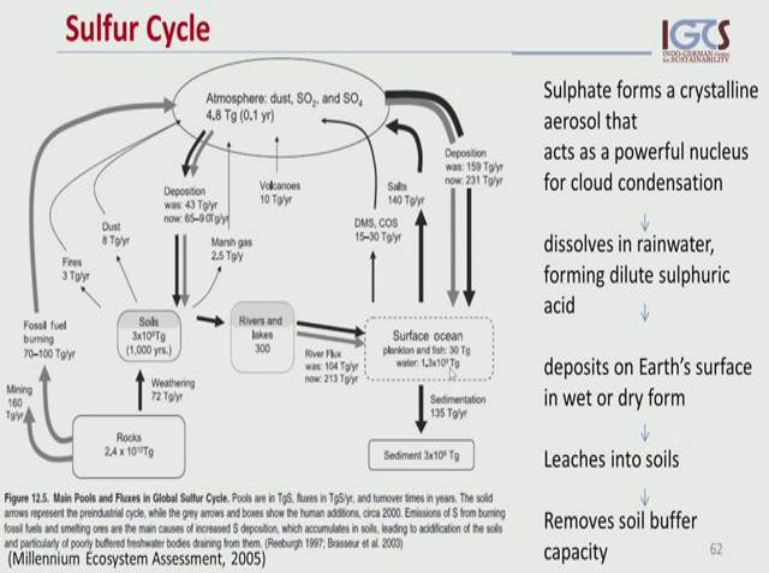
connection with our aquatic, our terrestrial, aquatic systems and even less of connection to our oceans. So, and it is basically no, very minor portion of the phosphorus ever reaching the atmosphere. This is natural. And we have changed this, the grey arrows indicate the flows that were a result of our human intervention.

We have been removing phosphate from minerals, from our geological storages and put this into, in additional cycle, that to increase our agriculture production. So, there is an industrial production of it, which has increased amount in soils and it has also influenced the amount of or doubled the amount of phosphorus, which is washed into our river systems and which eventually will reach our oceans again and influence aquatic course in, within our oceans. Now, what this means is that very little phosphate has been taken out by natural processes, by weathering processes out of our geological reservoirs.

So, phosphorus is, phosphorus is one of the least biologically available, however major nutrient. And what we, what we have observed is, by adding phosphorus to aquatic systems, rivers and oceans, they respond to a lot of a biological activity, which is by far larger than by adding nitrogen to aquatic systems. So, phosphorus is one of the limiting and driving nutrients in aquatic systems, however it played a minor role up to the point when we started mining and adding phosphorus to our as part of our fertilizers

So, phosphorus is also usually not transported in an absorbed way on soil particles. It requires, it is not in solution, it forms large colloids or large molecules, hydro particles or it absorbs, it gets absorbed on soil particles and only in that way, it is being transported. So, it becomes a major component out of soil, of sheet erosion, soil erosion, desertification processes washed out from land surfaces due to storm water events. And for that reason, increases from agriculture fields wash out into our aquatic systems. So, what phosphorus used to do, it has been moving in geological time scales and we accelerated it by the way, how we use our land water systems.

(Refer Slide Time: 18:00)



Now let us look into the sulfur cycle. It is also very interesting one, where we have a major storage compartment in the atmosphere. We have a very active linkage, very active cycle between the ocean, our aquatic ocean system and the atmosphere and we have only minor connection between the terrestrial system and via the terrestrial system to the ocean.

So, this is what it used to be without our human intervention and this changed substantially by, as releasing sulfur into the atmosphere, by burning fossil fuels by mining coal and using the crossing fires and dust and this is created in an additional cycle, that now originates from the terrestrial, from the land surfaces and contributes to the atmospheric compartment. And by that the major deposition again occurs over the oceans and substantial deposition also takes place over the land surfaces again.

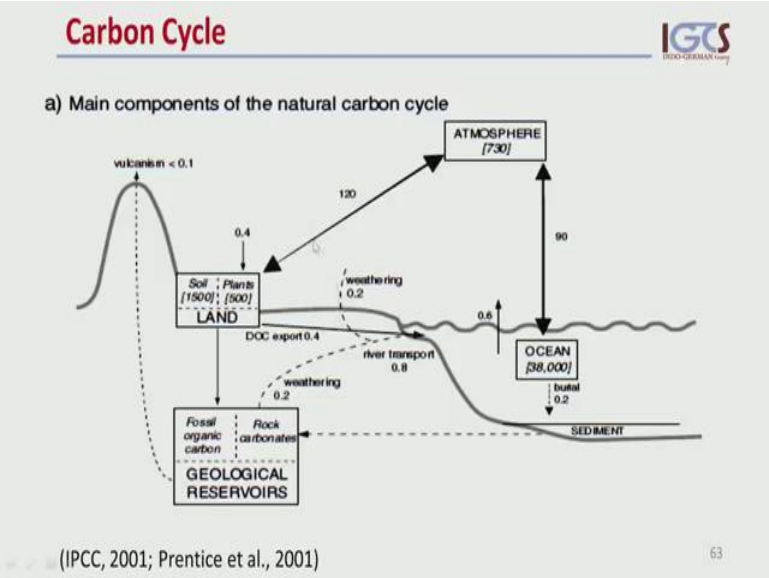
Now, what the impact is, what ((Refer Time: 19:57)) sulfate is, forms a crystalline aerosol that the way this occurs in the atmosphere as an aerosol, in many cases as a crystalline and it is in crystalline form and it is a very powerful actor for cloud conversation. So, while this maybe useful in situations where rainfall is being waited for, we can, we could think of using this as a mechanism to generate clouds into generated rainfall over a certain area. However, these sulfates dissolve in rain water and form sulphuric acid and that is a strong acid in itself, which reduces the pH in rainfall, in rain water, which then reaches the surface.

Now, this coming diluted in rain water and being deposited on all surface in wet form

first of all and later also in dust or dry form has major impacts on the plant life, on photosynthesis. Remember, the dead forests that were observed over large parts of Europe, large parts of the United States as a result of the deposition of acid rains. It also leaches the soils and by that reduces the buffering capacity of these soils. It has an impact on our constructions on buildings, buildings gets damaged.

You may be aware of the case of Taj Mahal where industries will stop to operate in this area to reduce the amount of damage and due to acid rains. Although this is only a local and you see this is a global cycle. So, what happens locally is only a minor impact factor on, in compared to what the surrounding areas, neighboring countries and so on are doing. It leaches to soil and it, it removes, it reaches the point where soil buffering capacity will be taken off. So, the effect is, that we have acidification of our ocean, which has a very negative impact on our aquatic life in oceans and again.

(Refer Slide Time: 23:20)

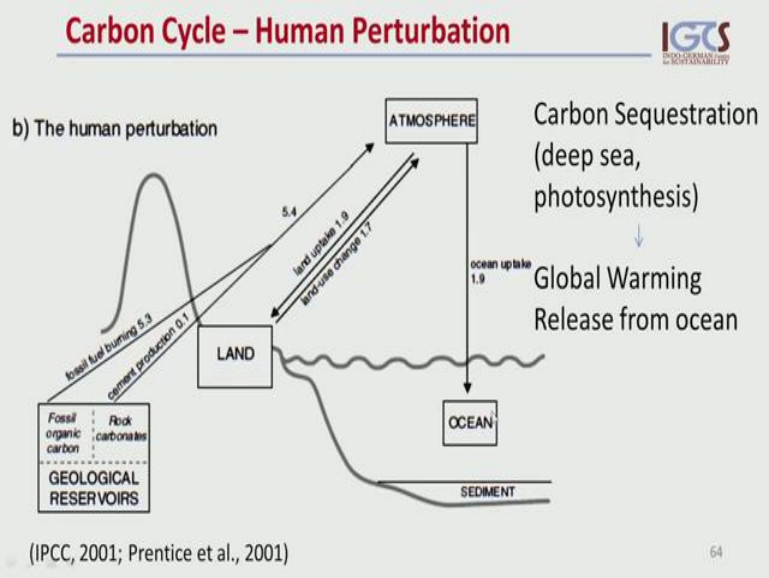


Now, lastly, I want to talk about, briefly talk about the carbon cycle and the best explanation you may find in one of these two reports here. And again, we have to look at first the natural carbon cycle, which is a triangle between a soil and plants on our terrestrial surface, on our land surface linking to our atmosphere as one of the compartments and linking this, those two to our oceans as a major, a major storage for carbon. This is our natural cycle and the major transportation pathway is from our terrestrial activities on the surface of our land to the atmosphere and then, into the ocean.

So, any of the weathering processes or any of the geological storage compartments have

not played any role as the ground water or the river systems have not played any role in this carbon cycle from a natural point of view. It is only minor, what has been washed out or transported in rivers or weathered.

(Refer Slide Time: 24:57)



Now, we know, that the carbon cycle has been changed substantially by human perturbation and nowadays, it looks very different. We still have our atmospheres compartment, we have our oceans as major compartment and we have our land. However, here we are not differentiating between what happens on the surface any more because what happens on our land surface becomes a minor, minor component of the carbon cycle. The major component or major storage input source are geological reservoirs.

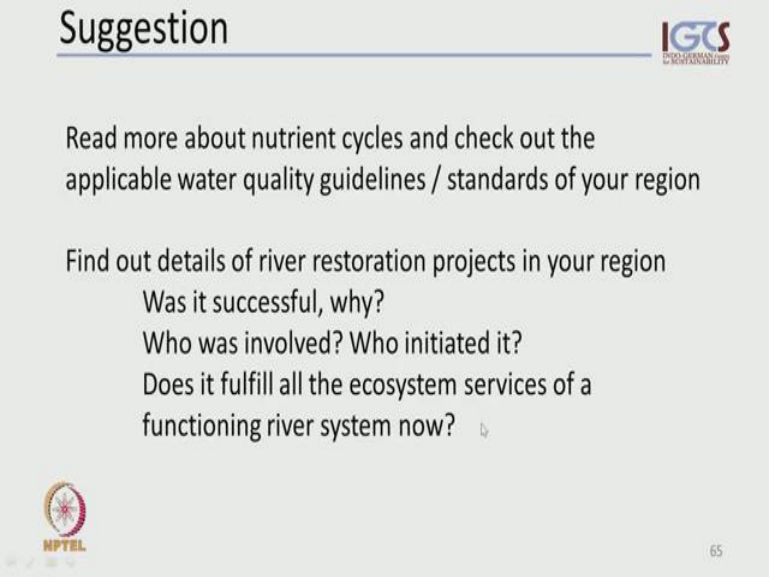
We all have been mining our fossil organic carbon, our gas, our oil, our coal deposits on one hand side. But not to forget also our hot carbonates, which we use for construction, for instance, for cement, for any large dam for instance, any large urban area, the rock carbonates have become very important. So, this is an additional we have formed, caused an additional cycle, which all in, all in itself is feeding back into our oceans.

Now, what happens, our, in our oceans we have, the oceans is our major sink for carbon, for carbon sequestration, plant synthesis, photosynthesis plays a minor role. Although there maybe forest encroachment been observed, which could be a response to more carbon types availability in the atmosphere, but the major sink or major storage for this additional release carbon dioxide our oceans, which thinking about our carbon system in

aquatic environments increases the acidity of our oceans in itself. It reduces the amount of organic life based, which based on carbonate structures. It destroys it, essentially, it reduces the biodiversity.

The same time, due to our global warming, we reduced the amount of carbon dioxide that can be stored in warmer ocean storage. So, at the same time we see a release of carbon dioxide from the oceans due to an increase of the temperature of our oceans.

(Refer Slide Time: 28:31)



So, those are the major changes that we can see and are measurable and which all of, all in themselves are quite moving to our own survival and to the function, especially of our aquatic systems, of our river systems. At this point, I want to close our second module and I want to suggest you two things. One, to read more about nutrient cycles, I could only touch very superficially, but they are extremely important. You should check out applicable water quality guidelines, you should get water quality standards of your region. You should also get information about acidification of rain, maybe there are pH measurements in rainfall and maps being produced for your region. We should try to get that information and to improve the understanding of this.

You should also, my suggestion is you should read about river restoration projects in your region. You may get information about what worked, what did not work, why did it not work properly or what was successful. For that reason special, who was involved in it, who actually initiated it, was is, was it the local population people that wanted it, was it a politician, was it someone else, who actually ((Refer Time: 30:19)), was it an NGO?

Does it fulfill now the ecosystem services and does it fulfill, maybe, all of the ecosystems service that we want from a functional river system and so on. You could think of more questions and it is not a homework, that I will ask you to present, but I want you to do that searching about such a, such issues and try to understand and learn more about that on your own.

Thank you. And I see you next time for the next new module again.