

# Sustainability Perspectives: What we can Learn From Alexander von Humboldt

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In many presentations, we have seen that people have introduced their friends, they brought a friend - I also brought a friend of mine, my scientific friend, Alexander von Humboldt, and his ideas. I invite you to follow some of his ideas during this speech, during this presentation. First, we will have a look at what Humboldt calls the "Naturgemaelde". I want to introduce some of his main concepts, some of his main thoughts, and based on these perspectives, I would like to invite you to come with me to visit some what we call "hotspots of climate change". We will take a closer look on what's going on there, on the ground, and what the intermingled and multiperspective dimensions are. And at the very end, we try to conclude what we have heard and define a kind of Humboldtian perspective, deriving a mission to approaching various global challenges.

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## 1. THE "NATURGEMAEDELDE" – HUMBOLDT'S HOLISTIC APPROACH

To start with, I would like to show you a satellite image of Lake Valencia in Venezuela. And this lake had and still has a problem. On the one hand side, it's very polluted. We can observe a lot of dispersing algae and other non-organic pollutants. But the second problem is that the water table became lower and lower. My question is ... and this is to you, to involve the audience. What do you think is the main reason? Why was the water table of this lake falling year by year? Any idea? Indeed, I expected you to answer its climate change and drought or other meteorological impact factors. Overpopulation and intense depletion of groundwater may be other reasons. Yes, you are right. And that's exactly what happens there; however, this observation is not a new one. Falling water tables were identified even more than two hundred years ago when Alexander von Humboldt visited the location on his expedition through South America. He summarized his explanation for the phenomenon as follows:

*"Those around the world who are cutting trees which are covering mountain peaks and mountain slopes cause a double nuisance for future generations, scarcity of firewood and*

*water. The intense and careless destruction of the forests which is practiced by European colonialists in America have dried out the lake completely or at least reduced the amount of water flowing in. By clearing the forests and due to the intensified cultivation of sugarcane, indigo and cotton all sources and natural inflow rates into the Lake of Valencia were gradually reduced year by year."*

Reise in die Aequinoctial-Gegenden des neuen Continents in den Jahren 1799, 1800, 1801, 1803 und 1804. Verfasst von Alexander von Humboldt und Aimé Bonpland. Band 3, Buch 5, Kapitel 16, S. 122

So that was an analysis Humboldt gave after local people have asked him: "What is happening to our lake?" At the end he was partly wrong because there exists a kind of natural sublimic affluence of the lake which he did not know. But that was his explanation for falling water tables.

And when we look at Humboldt's texts, I have just taken two quotations here, we find that he has an incredibly special scientific approach. For example, he wrote comparative texts about forests when he travelled through Venezuela and even discussed ideas about the negative ecological impacts of cutting trees in Germany, for example. We must keep in mind that, for instance, the Black Forest had hardly any trees at the end of the 19th century due to deforestation. That

was a fundamental problem in many European countries and referring to the problems in South America Humboldt wrote:

*“Taking into account the hot temperatures and arid winter months in America it is unbelievable that trees are cut here as excessively as in Franconia - causing timber- and water scarcity likewise.”*

Faak, M. (ed.)(2000): Alexander von Humboldt: Reise durch Venezuela. Auswahl aus den amerikanischen Tagebüchern.

Studying his texts, we can conclude that he had a highly holistic and overly complex approach. He looked at things from different perspectives, political perspectives, from the perspective of indigenous people living there. He was a very liberal person, not the traditional Prussian aristocrat. He supported the ideas of the French Revolution, was against slavery, and always gave references to historic and possible future developments. Humboldt tried to learn from history and extrapolated this knowledge into future developments. Furthermore, he was very meticulous and unbelievably detailed collecting and describing things, his companions must have become nearly mad about him because he was stockpiling and examining nearly everything in reach. He had a kind of rather differentiated sustainable thinking, covering social, economic, and natural dimensions. The way he combined ecological ideas with political questions underpins his liberal approach. Referring to his aristocratic home he said one day: “It will be a pleasure for me and I’m looking forward to leaving stifling Prussia”. As a matter of fact, he wanted to travel from his early childhood.

He wanted to define new ideas and explore new pathways. And his research was always intermingled, that means he tried to reflect on causes and effects.

And at the end, he was critical, not only related to politics, no, he offered a kind of critical reflection on science itself. He always questioned what his results were, what he was doing. And he tried to become better and better. Over the years he developed a kind of personality which was not easy. To my understanding he was a kind of narcissistic and even gregarious person: When Humboldt entered a room, everybody became quiet. And then he started talking. Talking, talking, talking. And after an hour, he left the room and spoke to nobody. Even when young Darwin wanted to meet him, he replied: “oh, this young fellow I don’t want to talk to”. I don’t know exactly because I haven’t been there. But I think he was, in a certain way, he was quite arrogant.

Another interesting aspect is that he was an expert in promoting himself. As an example, he published newspaper articles about Alexander von Humboldt in the Indian Times. So, he wrote anonymous texts about “great Alexander von Humboldt, who was the inventor of ..., the person who discovered this and that”. But, however, he wrote these articles on his own and sent them to the newspapers for publication. I guess, today he would be a master in using Instagram and Twitter. Humboldt would Twitter all day long informing his followers about his trips up and down the Orinoco and many more.

Finally, I would like to present a quotation which, I think, summarizes his approach perfectly well:

*“In the context of manifold intermingled causes and effects no substance, no activity must be observed isolated. The*

*balance amidst the perturbances of quarrelling elements results from the free game of dynamic forces. And a complete understanding of nature, the final objective of all physical studies, can only be achieved, if no force, no formation is neglected, and that is likewise the preparation of a wide and fertile field for the philosophy of nature.”*

Bonpland, A. und Humboldt, A.v. (1807): Ideen zu einer Geographie der Pflanzen nebst einem Naturgemälde der Tropenländer. S. 39–40

That’s what he had in mind when he talked about the “Naturgemaelde”. He always saw nature as a gorgeous painting, but for him the painting was more than just drawing and reflecting and mirroring things. The painting is full of empathy and full of imagination, understanding and, above all, question marks. In this way he referred to his natural environment as a kind of piece of art.

Having this kind of multi-perspective approach in mind, I want to invite you to visit some of the “hotspots of climate change”, I try to adapt to the Humboldt perspective when we look at climate change-related problems.

## 2. “HOTSPOTS” OF CLIMATE CHANGE – THE HUMBOLDT PERSPECTIVE

First, I must underline that I fully agree to what my colleagues, climate researchers, climatologists, meteorologists, and others have documented. There’s no doubt that the temperature has increased dramatically over the last decades. As a related aspect the average sea level has risen at least 20 cm within the last century. As the IPCC states *“Global surface temperature was 1.09°C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59°C) than over the ocean (0.88°C) [...] Global mean sea level increased by 0.20 m between 1901 and 2018.”*

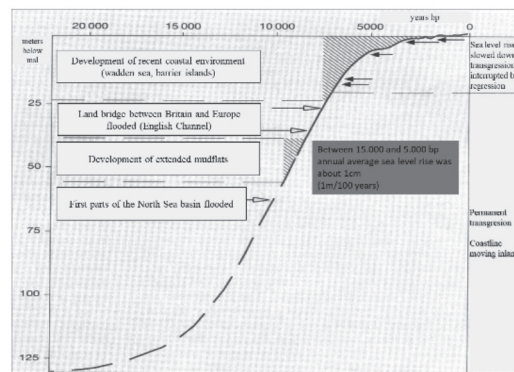
IPCC (2023): Synthesis report of the IPCC sixth assessment Report (AR 6).

[[https://report.ipcc.ch/ar6syr/pdf/IPCC\\_AR6\\_SYR\\_SPM.pdf](https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_SPM.pdf)] accessed May 8th, 2023

It is obvious that we observe an anthropogenically evoked climate change, and that the main factors behind it are the emission of carbon dioxide and methane. I need to say that in advance because you will now see some examples where we investigate local effects of climate change from a more critical perspective. But employing, what I call the Humboldt perspective, is essential and necessary to decide which steps are we going to go to handle, to manage the problems. Because I’m talking about some sea level related problems, I would like to introduce the following sea level graph.

At the very end of the last ice age, let’s say about 22,000 to 18,000 years ago, after the maximum of the last glaciation, we had a sea level that was 125 meters below today’s sea level, vertically. In other words, we had no North Sea. We had no deltas.

Imagine coastlines around the globe, at a level of today’s 125 meters isobath. As a matter of fact, you had to walk several kilometres outwards to reach the shoreline. So, no North Sea. And after the glaciers or while the glaciers started melting, we had a dramatic increase in sea level. First parts of the



**Figure 1** Sea level graph covering the past 20,000 years. Adapted and modified from Freund, H. & Streif, H. 2000.

North Sea basin were flooded about 10,000 to 9,000 years ago, geologically not long ago. However, we still had solid land between England and the remaining parts of Europe. About 7,000, 6,000 before today, before present, the land bridge between Britain and Europe was flooded. That was our, I would call it Brexit 1.0, that was the time when the channel developed. So just 6,000, 7,000 years ago. During Roman times at about 2,000 before present, the sea level rise slowed down. And during the last two and a half thousand years, we observe a kind of equilibrium. We have a kind of balanced situation with rising sea levels, regression and transgression characterizing our global coasts. All deltas around the globe have developed under the conditions of rising sea levels, due to the effect of sediments delivered into the ocean by rivers. At the point where rivers meet oceans, the mouth of the river, the transport energy is reduced dramatically. And at this point sedimentation takes place. That's the triggering moment why all deltas of the earth have developed. But we come to that a bit later. An interesting aspect can be seen between 15,000 and 5,000 before present, during this time span the average sea level rise was about one meter per hundred years, one meter per hundred years! Even under these dramatic rising sea level conditions, deltas around the globe kept growing. That's an interesting aspect to be kept in mind. Furthermore, our coastal environments have developed under these fluctuating conditions.

So, let's look at some hotspots of climate change, for example, Bangladesh. In 2007, that was the period when discussions about Bangladesh intensified, you can read statements like that: "Bangladesh in the death zone of climate change". Death zone. How dramatic is that? The death zone of climate change. And then the article informs: "Due to climate change sea levels are rising and, as a result, threaten the living space of millions of people. Bangladesh's extremely poor population is dramatically threatened, many huts are only centimetres above the flood level. And they don't even know anything about the danger of rising oceans. [...]". How arrogant is that? How post-colonial is that? In our research projects, we have discussed and answered the problem of climate change with hundreds of people, local people in Bangladesh. We have interviewed many people. We have published a lot of insights. And yes, they know about their natural environment. They are not stupid. They know exactly

what happens in their country. Local farmers, they know exactly, we have a climate change problem, we have an erosion problem, we have a problem with this and that. They know exactly what is going on around there, in their surrounding environments.

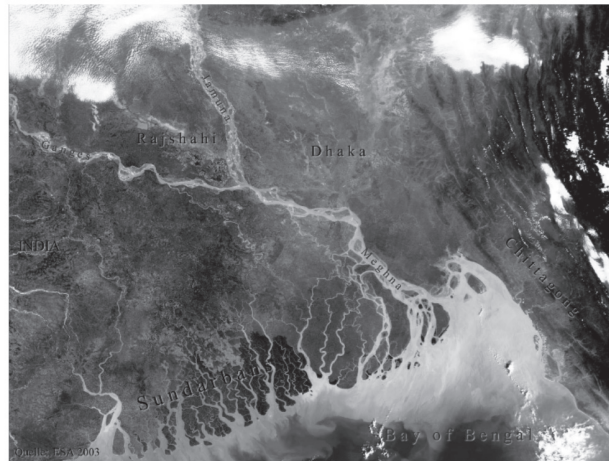
When we read dramatic reports such as the one quoted above, the only answer could be, okay, we are helpless. We can do nothing. But there are lots of things we can do because it is not a hopeless situation. Let's remind the Humboldt perspective. The Humboldt perspective is much more than just looking at the aspect of rising sea levels. So, let us analyse what is really going on in Bangladesh.

Bangladesh, as I have already said, covers a large delta area, the Ganges Brahmaputra Delta. It is one of the largest deltas in the world. And it developed over the last 15,000 years. It is a young, geologically very young sediment body. It developed due to rising sea levels. Firstly, at the beginning of marine transgression, the Bay of Bengal moved northwards. The water table, the ocean table rose.

As can be seen in the satellite image we have a dramatic inflow of sediment. Sediment load of the Ganges Brahmaputra River system. You can see these brown fans of sediments here which indicate the deposition of sediments. Sediments are delivered into these local coastal systems there.

Up here are the Himalayas, from which the material which is transported down to the coast by rivers stems. A mighty, giant orogenic complex. As a matter of fact, the sediment bodies constituting the whole delta complex are very mighty and also characterized by shifting waterways and tidal impacts. The material is very fertile, and permanently shifted. Originally the coastal area was covered by fringing mangrove forests, a wonderful environment.

This is a high tide image of mangroves covering the coast. You can see these brown waters here, a habitat for river dolphins and many other species. This is a wonderful environment. Thick mangroves, the Sundarbans, which means a beautiful forest. But, and now comes the but. This system here, the mangrove forest system and the sediment loaded rivers, is the key element for constituting the delta body. Regular flooding tides, low tide, high tide, sediment loaded rivers and the loss of energy at the point when the river enters the ocean. Sedimentation takes place exactly at this equilibrium line. Originally there was 60 kilometres, imagine



**Figure 2** The Bangladesh coastline seen by Envisat. [https://www.esa.int/ESA\\_Multimedia/Images/2005/03/The\\_Bangladesh\\_coastline\\_seen\\_by\\_Envisat](https://www.esa.int/ESA_Multimedia/Images/2005/03/The_Bangladesh_coastline_seen_by_Envisat)



**Figure 3** Sundarban mangrove forest at high tide. Falk, G.C. 2015.



**Figure 4** Shrimp farms have replaced traditional forms of land use. Falk, G.C. 2015.

60 kilometres, wide fringe of mangroves in the natural system, it was wonderful. This is the situation under which these Asian deltas have developed. You can compare it to other Asian deltas, in India, in Thailand. It was nearly the same situation. However, these mangroves have gone, not only just

a few of the mangroves. Look at this picture here, this picture illustrates the situation today.

Up to 85, nearly 90 percent of all fringing mangrove forests have gone. And the reason is that we have changed the landscape. And I think I can say we, because we are the



**Figure 5** Coastal landscape in Bangladesh pre and after shrimp farming. Falk, G.C. 2015.

consumers of what I would call the white gold of Bangladesh, or other Asian countries: shrimps. Shrimp farming replaced traditional forms of land use. Up to 40 years ago a system of local traditional farming existed: small villages, honey harvesting, combined with some rice fields and some small ponds, fishing ponds. That was the traditional system here, but it was replaced by extensive aquaculture, shrimp farming. In many areas there are no mangroves left since shrimp production has increased dramatically over the years. So, that is why I say we have contributed to and supported the change of this coastal environment. And you see, this is a dramatic change. We have no shadow. We have high evaporation rates. And the problem are these aquacultures, we are not talking about just a little part of the coastline, we are talking about 90 percent of the land surface which has been restructured in this way. No shadow and high evaporation rates mean that a lot of groundwater is needed. Depleted groundwater and freshwater are necessary to compensate evaporation and transpiration, because shrimps need a certain amount of fresh and sea water, brackish water. Different kinds of shrimps need different kinds of brackish water. Fresh water taken from the rivers must be pumped into these systems permanently. And, in addition we have high evaporation rates. All in all, that means you can use such a shrimp farm for about 15, 16, 20, up to 20 years. And then you cannot use it anymore, it's a problem. It's over. A particular problem are the high mineralization rates of the soil.

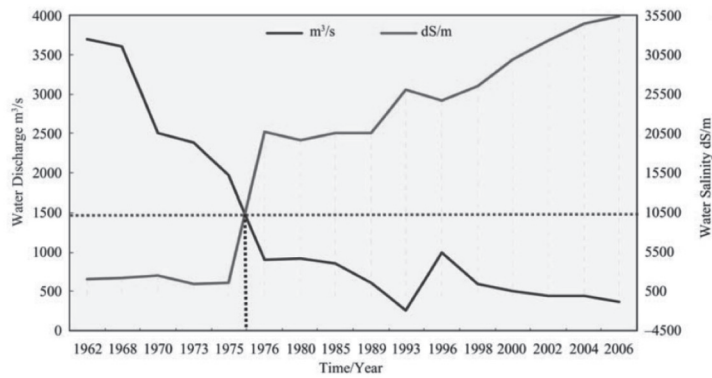
The question is, how to use the land when shrimp farming is not profitable anymore? While we, while our NGOs are still discussing to establish floating gardens to protect people from rising sea levels these unused shrimp farms are now transferred into industrial complexes. A power plant was erected next to the Sundarbans (a world natural heritage site). Shipyards and factories are built along the rivers where former shrimp farms have been.

The environmental problems are serious. Look at this photograph I have taken on a boat tour, by the way, I went to Bangladesh quite often, even with students. I brought them with me. You have the perspective from where I have taken the photo.

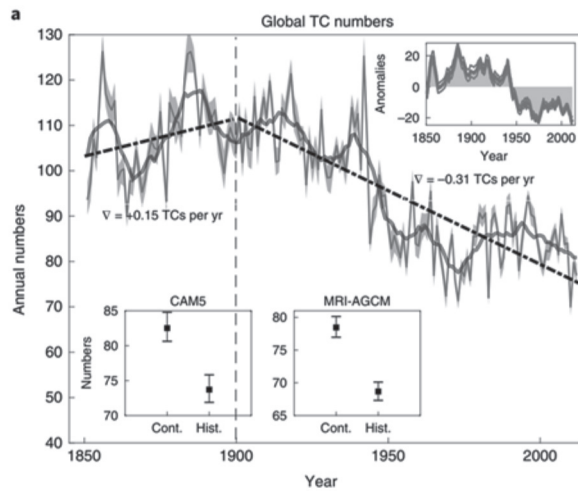
To the left, you have the fringing mangrove forest, the remains of some of the mangroves which are left. And on the right-hand side, you can see an area where they have already transformed the landscape into aquacultures. You can see the difference here, there is no erosion. Sediment accumulation and compaction takes place in catchment areas where thick mangrove air routes catch the sediments. And on the other hand, erosion and a shifting riverbed can be seen, this is a serious problem there. As you can see, this negative situation there would happen, with sea level rise and without sea level rise.

Let's look at the next aspect: salinization. When you read publications about salinization in Bangladesh, the first aspect you usually read is: due to rising sea levels we have a salinization problem. At a first glance we can agree. Rising sea level means that saltwater has an impact further inland. And that means, okay, we have salinization, which is somehow shifting landwards. But remember the Humboldt perspective, Humboldt would ask, is that really the case? Or are there perhaps other reasons for salinization processes? One aspect is that people pump out groundwater into the ponds for shrimp farming and high evaporation rates due to missing shadow. We have summer like long hot, dry periods leading to evaporation and salinization, that is another reason. But when we look at the major rivers here, this graph documents the situation near Passur River. This is a graph; I think it is very impressive.

When you look at the water salinity and when you look at the development of water salinity, you can see this little dotted line here. You can see that in 1974, 75, the salinity of this river at this location near the coast rose dramatically. The amount of water running down this river was reduced dramatically. So, less than 500 cubic meters per second nowadays, from 3,500 cubic meters per second before 1974. This is strange, isn't it? Imagine you have a salinization problem and for political reasons you blame sea level rise. But on the other hand, you reduce the impact of freshwater, you just turn off the freshwater. It's no surprise that salinity is increasing in coastal areas when there is no water, just a very small amount of water is still reaching the coast. This is a very easy to identify aspect. What happened there? We have this "wonderful" building



**Figure 6** Ganges water flow decrease and salinity increase, as measured at Passur-Mongla point.  
 Note: Vertical dotted line indicating building of Farakka dam in 1975. Islam and Gnauck (2008).



**Figure 7** Declining number of Tropical cyclones. Chand, S. et al. 2022: Declining tropical cyclone frequency under global warming. In: Nature Climate Change, 12: 655–661.

here at the river Ganges, on the Indian side, before the river enters Bangladesh, they have erected this giant dam. It’s the Farakka Barrage. And they have dammed, simply dammed the Ganges, and diverted all the water, which you can see over there. This map that doesn’t show the truth, because here you can see a river which does not exist anymore. We did some research projects there, there’s nearly no water left at certain times of the year during dry season. India uses all the water and diverts the water into India. Bangladesh has a serious problem, a water problem. And that’s the situation during dry time and imagine what India does during monsoon time? Open the gates! Consequently, Bangladesh is flooded with an extra amount of water flowing into Bangladesh. And imagine what, for example, a state like Egypt, a military strong state, would do with this dam ...causing these severe and serious problems here in Bangladesh. The calamities result from a combination of a lot of impact factors there. And as you can see, we have not talked about climate change yet. We have talked about a lot of dimensions and a lot of problems people have. But climate change is still to come as an add-on.

We are not there yet...Cyclones are another interesting story. I found a publication which documents that the number of cyclones is decreasing in the Gulf of Bengal, but I didn’t

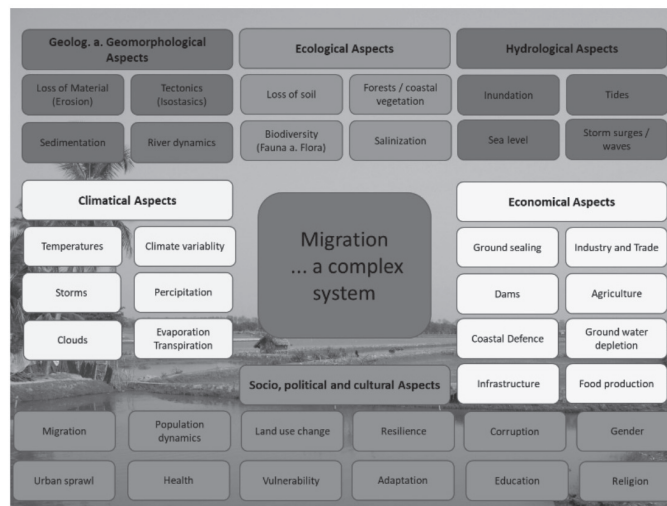
trust this information, I was sceptical about this. The number of cyclones decreasing? That does not fit into the discussion of climate change and what we can read. I always try to double check and most recently, there is this, I would call it a “revolutionary” or just enlightening publication in natural climate change.

Chan and others document that the numbers of tropical cyclones, the global numbers of tropical cyclones, is decreasing during the last 50 to 40 years, “on average, the global annual number of TCs has decreased by about 13% in the twentieth century compared with the pre-industrial baseline 1850–1900. [...] Importantly, a much larger decline (23%) is evident after 1950, coinciding with a period when warming signals in the climate system became evident in the historical record.” (Chand, S. et al. 2022)

That triggers question marks and there are different explanations for this graph, explanations why the number of cyclones is decreasing. I just want to illustrate that with a short example, to make the complex cause and effect structures clear, let’s talk about tornadoes for a moment. Rising temperatures can be observed in Northern Canada. Canada and North America are particularly warmer, the continental landmass warms up more, compared to the more southern



**Figure 8** Are the people living in the slums of Dhaka climate refugees? (Falk, G.C. 2015).



**Figure 9** Aspects impacting migration. (Falk, G.C. 2023).

Gulf of Mexico and water bodies. So, we have warming water bodies, but much more warming continents. And this means that the temperature difference between tropical waters and the warming continents, North America, Canada, is less than it was 20, 30 years ago. Due to global warming processes. These temperature differences, which are reduced, lead to a decrease in cyclones and tornadoes. Looking at cyclones we must consider many other impact factors like the varying Walker circulation, which is responsible, also responsible, somehow teleconnected to the effects of cyclones in the Atlantic and so on and so on. But this would be another presentation ...

The question is, are these people we have interviewed in Dhaka, are these people climate refugees? When you read news magazines, you always read about climate refugees. We have asked them, are you a climate refugee? And they said, no, we are not a climate refugee. We cannot find a living anymore where we have been before because we were expelled partly by force some years ago due to the land use change structures, because landowners wanted to generate new places for agriculture. So many people had to leave their

local environment for economic reasons. And we are a key factor in this process because we are the consumers of cheap shrimps. When I was a child, there was one shrimp on a salad, and everybody wanted to have this shrimp. And they said, oh, they're wonderful, one shrimp. But nowadays we can buy a kilo of shrimps, deep frozen, just for eight euros, ten euros, five dollars or whatever, they became very cheap.

Another aspect is the aspect of population pressure. We had char-dwellers, people that were living in local coastal systems, on islands. Imagine shifting riverbeds in this natural aquatic system, in this amphibious system. So, once an island is flooded, they could move to another island. This is a shifting cultivation system people had, and this worked up to a certain amount of people. 100 years ago, I guess we had about two to three million people living in what Bengal was or later East Pakistan and then Bangladesh. So, we had, let's say, two to three million. Now we have 150 million, or even more people living there, they cannot just move from one place to another. If there is flooding, if there is erosion, due to many reasons I have already mentioned, they cannot leave their villages. They have to move.

I will go on a little bit; you don't have to read all of this, but I have tried to summarize all the aspects. And the question is, are they climate refugees? No, they are not climate refugees. They are refugees due to changes in all these different categories here. We have storms, that has an impact. We have different precipitation patterns, different monsoon rains, different patterns, thunderstorms, dry season. We have land use change, we have resilience. People try to stay where they are, they don't want to leave their homes. And we have corruption, education, adaptation. We have gender aspects. Male people are leaving the villages first, causing trouble for the women remaining in the village. All this has a dramatic impact on societies. To summarize that, an increasing number of floods is primarily owed to land use change and not to climate change. This is a serious problem in Bangladesh. The character of flood events is changing. Imagine you remove the forest. You have more intense wind, no ground friction, higher wind speed. You have faster moving water bodies, higher waves. As a matter of fact, the dynamics of floods has totally changed since they have removed the protecting mangrove forest. And land use change causes massive social disruption. People must leave. An intact mangrove fringe would increase sedimentation rates. Sedimentation of river compensates the sea level rise. Eastern parts of the deltas are still growing to intense sediment input. You remember the satellite image with these brown fans of sediments flowing inside and reduced runoff rates of the rivers. That are the key factors for salinization. And, in addition, we have the problem of climate change. Climate change leads to another 20 centimetres of sea level rise, to other dynamics of increased salinization, but the main problems, the reasons for the problems, can be found somewhere else. The question is, so what can we do with that? On the one hand side, we are responsible. The impact we have is on the carbon reduction and things like that, but that alone does not really help people in the global south. We have to modify, to rebalance our consumerism. We must ask questions ... And to go even further, we have created a double, double, double win-win situation for the global north – and this is really cynic! By consuming shrimps, we have supported the process of removing people from coastal areas. And we have set free a giant workforce. And do you know what these people are doing? They are working in the garment industry. Isn't that profitable for the global north? "Wonderful" ...

The situation is even more dramatic. If it just were climate change, we could relax, we could try to reduce carbon dioxide. But it's more than that. Systems are much more complex and much more challenging at the very end.

Let us travel to the Maldives, to coral reefs. You can read that the Maldives will be "swallowed by the ocean in 2100". Oh, that sounds dangerous. The world has witnessed the government doing a kind of underwater conference. You all remember these images; they intended to lead the attention to the potential dangers of climate change. On the other hand, you read articles stating that "the Maldives could grow with a rising sea level. Over the last 10,000 years the sea level has been rising a dramatic 15 metres per 1,000 years – The reef rings have been rising to the same extent. Under normal circumstances the estimated sea level rise of the 21st century

should easily be compensated by reef growth." We have already discussed the rates of a rising sea level before. So, let's have a look at such a coral reef, a closer look at a what we call Holocene reefs, the Holocene began 10,000 years ago. Those reefs have developed over the last 10,000 years, and keep in mind, in this period, sea levels rose dramatically. What's the character of a coral building the coral reef? Rising sea levels mean corals are growing, they are growing. The faster the sea level rises; the faster corals grow. Drilling a hole into the Holocene reef, you can easily identify periods when the sea level rose faster, and periods when the sea level rose with less dynamic rates. Compact corals mean slower sea level rise because they did not grow that fast. During the Atlantic period, for example, when we had dramatic rises in sea level, they grew very, very fast. We have rising sea levels, why should they stop growing? There's no sea level related reason for coral reefs to stop growing - that's the basic idea geologists, geomorphologists and earth scientists all around the globe share. That's a perfectly simple assumption. So why should this reef systems stop now although the sea level is rising? Corals will keep growing or start growing even faster, that should be no problem. But somehow there seems to be a problem, and yes, indeed there are problems in coral reef islands. But what is the problem? The problem is on the one hand side sewage, water pollution, and in discussion, acidification of the oceans, and rising temperatures, which leads to coral bleaching. This is a serious problem. Anyway, there are already a lot of research programs discussing coral bleaching. Researchers are always surprised that, for example, the Great Barrier Reef recovers even after the most severe coral bleaches. It recovers for some reason and the idea of my colleagues is that the corals which live in symbiosis with the zooxanthellae just try to get rid of the algae, which are not resistant enough to rising sea levels, not resistant enough to rising temperatures in the oceans. However, after a while they are replaced by other kinds of algae, that's one reason why there is the potential for reefs to recover after coral bleaches. There is also a discussion about the interaction between carbon dioxide, oceans and the impact of rising water temperatures. This is also contradictory because rising temperatures in the ocean means we have less dissolved carbon dioxide. All in all, our oceans are a carbon sink and the cooler the water, the more carbon dioxide can be absorbed by water, which leads to more carbonic acid. The water body becomes more acid an effect that may have a long-term negative impact on corals. Doing research on the dimensions of different coral reefs, reputed colleagues from Auckland University, Paul Kench and others, did a lot of research in different coral islands, Tuvalu, for example. And their findings are really stunning: "[...] Here we present analysis of shoreline change in all 101 islands in the Pacific atoll nation of Tuvalu. Using remotely sensed data, change is analysed over the past four decades, a period when local sea level has risen at twice the global average ( $3.90 \pm 0.4$  mm. yr<sup>-1</sup>). Results highlight a net increase in land area in Tuvalu of 73.5 ha (2.9%), despite sea-level rise, and land area increase in eight of nine atolls. [...] Results challenge perceptions of island loss, showing islands are dynamic features that will persist as sites for habitation over the next century [...]" (Kench, P. et al. (2018)





**Figure 10** Malé viewed from the west.

Image source: Shahee Ilyas (CC Attribution-Share Alike 3.0).

Surprise, surprise when we read that. Particularly when we compare the findings with information published in Greenpeace magazines about Kiribati and Tuvalu and other island locations. How can that be? Is there no problem? Or what is going on there? Kench et al. (2018) state that “results challenge perceptions of island loss, showing islands are dynamic features that will persist as sites for habitation over the next century [...]” Where is the truth? And what can we do with this information? How would Humboldt investigate this hot spot of climate change? When we look at inhabited coral reefs, we see something like that. This is Malé, the capital of the Maldives.

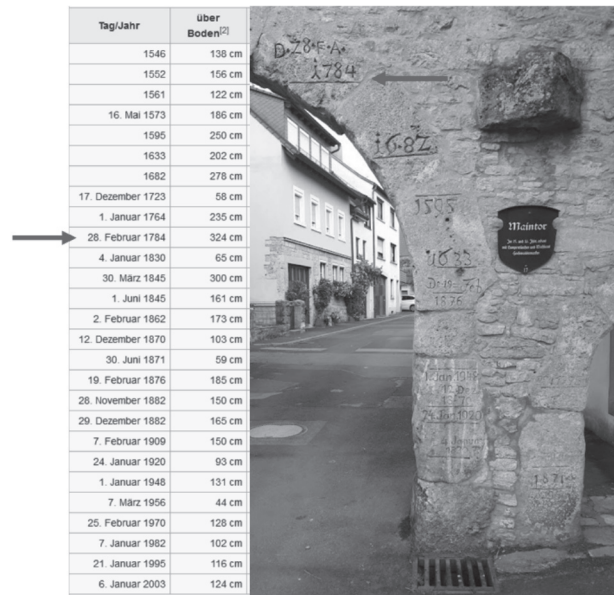
You have already got a little impression how a coral reef develops, how it grows. Corals grow and in case of a storm, some upper layers are broken apart, they are flushed into the island. All in all, the sediment, the coral sediments, coral sands, and the coral reef as a naturally intact system will adapt to different sea levels. But these people here, can you see what they have done? There is a dam around the island. There is no chance for any growth of corals here. On the contrary, they have built concrete buildings, skyscrapers on very fragile corals. Corals show enormous compaction rates, they are sinking themselves. Even without sea level rise, the inhabitants would have a problem because the structures are too heavy. The weight of buildings, the compaction of the coral base, sewage discharge, water pollution and coastal protection dams prevent sedimentation. And interestingly, the findings of Kench et al. document that “eight of nine atolls are increasing”. Imagine which is the one that does not increase...This is one aspect; another aspect is coral bleaching. Just to say they have a problem because of climate change and rising sea levels is far too simplistic.

I think it is necessary to discuss how to react under the given circumstances. Yes, there is a sea level rise related problem for them. It's there, sea levels are rising due to climate change. In uninhabited islands it might be not a problem, but here in Malé they have a problem. Actually, Kench and others, even recommend shifting settlement patterns, moving people from one island to the other. An interesting aspect, but we don't know. My time is nearly over, isn't it? Okay. So, just two more examples. Just to mention it. We have the same complex systems when we talk about river flooding. For example, in Germany, we had a severe flooding in 2021. However, when we look at rivers and historic flood events, we learn that we

have had much higher flood levels during the last centuries. 1784, I would not have liked to live in Europe in 1784. It must have been the most dramatic year we ever had. The Laki eruption in Iceland caused dramatic weather patterns in Europe and we had severe flooding here in 1784.

For example, this is Wurzburg, near Wurzburg. I have taken this photo of the city gate of Eibelstadt. Have a look at our millennium flooding here - and this is 1784. We had a very special situation in 1784. We had ice in winter, it was very cold, and all rivers were frozen. It was very cold because we had the Laki eruption in Iceland the summer before, which was still ongoing. It was particularly cold in Europe. Suddenly, around the 28th of February, at the very beginning of spring, we had rising temperatures and Winter came to an end. Intense rainfall started combined with melting snow from the Alps and from surrounding hills and mountains. And all the water tried to enter the rivers, which were still frozen, and the ground was frozen too. There was no chance for the rain and the waters to just disappear. And this caused a very serious flood event in 1784, this was a millennium flood.

However, climate change has an impact on flood events, there's no doubt that the number of heavy rain events will increase. But for a river system, for example, the Ahr River System in Germany or others, that simply means that the rate, the chance of a flood event will increase, from every 100 years or 110 years to every 105 years. There will be a slightly higher chance of flood events. But that does not mean that the flood event will not take place anyway, it may occur more frequently. And if you count all river systems, for example, in Central Europe, that means we will face flood events more often. But for the local river systems, the vulnerability has other, much more important reasons, the problems result from inadequate land use practices, such as people who have built their houses or infrastructures next to the river. When you look at the river Ahr, for example, as a geomorphologist, when you look at the riverbed, which is at the bottom of a V-shaped valley, you know that this valley has developed because of flood events and intensified run-off rates, that erosion has created this valley. The problem is that people have built houses next to the river, which regularly leads to catastrophic events. Looking at various flood influencing components, climate change is by far not the strongest impact factor. Land and soil sealing, soil compaction, changing of riverbeds, loss of floodplain, deforestation of slopes, a missing collective memory and so



**Figure 11** Historic flood marks at the city gate of Eibelstadt (Germany). Source: Falk, G.C. 2021.

on are even more significant. From a Humboldt perspective, there are many aspects to be considered, just to say it's climate change that leads to flood events is very short-sighted.

Pakistan is another prominent example for complexity and the need of a holistic approach. This aerial photograph shows a monsoon related flood event. It is well documented that monsoon patterns have changed over the last decades. However, when it comes to inundation the causal link between more intense rainfall and flooding is, again, to simplistic. Politically it is easy to make climate change a universal scapegoat for everything. I found this wonderful sketch; it illustrates the situation uphill: reckless deforestation! An easy explanation for flood events can be derived from observations on the ground: irrigation projects, canalisation of rivers deforestation, modified affluent systems, and high population density are the main reasons for an increasing vulnerability to flood events in Pakistan. Upstream in Nepal, for example, nearly all the forests have been cleared. So, it's no surprise that flash floods (upstream), high water tables and intense flood events (downstream) occur more often. Anyway, climate change induced modified rainfall patterns aggravate already existing risks!

Last, but not least, I would like to draw your attention to coastal cities in Asia. Here you can see the red line, this line shows the sea level rise, which is about 20 cm during the last century. That's sea level rise. And what you can see here, that is the rate of sediment compaction in different towns. So, for example, when you look at Bangkok, we did research there. Walking through Bangkok, you're surprised. You see numerous new buildings, and everywhere, they have a problem with their foundations, problems related to the sinking surface. People have erected their buildings, their houses on sinking surfaces. The reason for the problem is intense groundwater depletion for millions of people that are living in Bangkok, for example.

Look at line indicating the subsidence of Bangkok. We have minus one meter due to subsidence. Removal of groundwater,

groundwater depletion for industrial purposes, for drinking water. Even up to 1.5 meters in central parts of Bangkok. And in relation to that, yes, we have rising sea levels. But that is not the main problem that makes these cities flood prone and vulnerable. You can imagine what happens when they have to face their next flood event in Bangkok. Climate change will be blamed! Nobody, no politician will talk about the misuse of local resources, drinking water, inadequate irrigation projects and other man (self) made causes.

### 3. INFERENCE AND MISSION

Climate-induced changes do not represent all aspects of the complex earth system. Often vulnerability is a result of inappropriate land use and climate change. Climate change merely acts as an enforcing component at certain sites as we have heard. Around the globe, there are many other sites. If you want to see the immediate effects of climate change, go to the Iceland glaciers, glaciers in Iceland. It's terrible. They are melting down dramatically. Yes, we have a serious climate change problem. But solutions need more complex questions and answers. The impact of land use change is under-estimated yet, as many climate models and predictions often neglect human activities on the ground. However, human-induced climate change remains a serious problem!

As a summary for the conference, I would like to underpin the Humboldtian holistic perspective. We have to live with the complexity of systems. The manifold intermingled causes and effects need problem-solving by asking holistically fitting questions. Spoken in the Humboldtian way, we must put reliability versus ideology. Trust, and that's the aspect of this conference, trust and reliability is based on thorough research, multi-perspective and interdisciplinary approaches, holistic and flexible views, honest research, and the acknowledgement of limitations of research. And finally, the third mission is a very important thing for us as scientists, simplifications

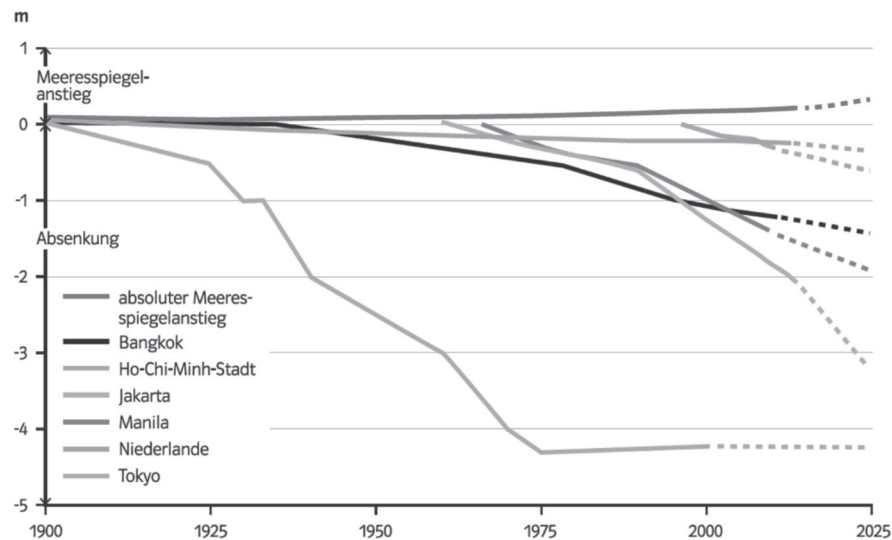


Figure 12 Delta subsidence and sea level rise. Source: Falk, G.C. 2016.

may cause mistrust. People don't want to be cheated. They want to get informed. Let's look at the basics but let us document the complete story of pros and cons, people want to analyse the problems on their own. Complexity needs intelligent science communication and enhanced knowledge management. For example, smart tools, apps, artificial and artisan intelligence. As Humboldt says: *"Those who observe from a reflective perspective recognize nature as a unity in diversity, as a connection of the manifold in form and mixture. The embodiment of natural forces and phenomena as a living whole."* (Humboldt, A.v. 1845)

And this is my final word. As mankind, we are just part of the living whole and I think a more modest, a much more modes approach is necessary. We have influenced the earth systems, we have heard about the Anthropocene, we have heard about Paul Cruzen. I think the approach of sustainable development, that follows the idea that we human beings are the "great developers" of everything is a problem. This anthropocentric approach is really problematic. We are just part of the living whole, and I would say we should change our view and talk about a kind of sustainable engagement in earth systems and cycles. I didn't find a proper English word for it. In German, I have described this approach as "Nachhaltige Teilhabe am System Erde". So, I translated "Teilhabe" with engagement, but I'm not really happy with that. "Teilhabe" is somehow different than engagement, but I didn't find an adequate word for it. Maybe your masterminds have a fine solution for that translation problem. We are all on a long but not hopeless way towards more sustainable engagement. Thank you very much for your attention. It was a great pleasure to have been invited.

#### 4. Q&A

**Q:** I don't have a question, but I want to say thank you. You opened my eyes. Thank you very much. Especially that year 1784. In 1785, my ancestors left Germany. Yes. And went

to the Danube River. Yes. To colonize it. Yeah. To make the river that was dumped in Malaria area. **A:** We urgently need to write a novel just called The Year 1785 or 84. And then put everything we have inside, storms and flood events and all the catastrophes. Wonderful. Thank you very much. I'm a little bit related to your talk. I'm very interested. **Q:** Also in fake news. And what you were talking about is insights that scientists have that maybe not even the local people have. Because it's a complex intertwining of things. And you also do a lot of education. So how can we educate the people that they know the reality and these more complex connections between the things? Yes. And how can we make them understand the reality? Because I think knowing it, as you also said, it's like the first step towards eventually solving it. And as people are trying for easy explanations like climate change, even if you have the brightest minds, they're maybe not targeting the right things. **A:** I think the problem is that there is actually is no reality. We can just put puzzle pieces together. And we do research work at the North Sea coast. We do research. We ask people. We interview people. We work with satellite images and describe how sediment systems are modified and how sedimentation patterns are changing. And how many people are moving from A to B and why they did it. And we do it with qualitative interviews. We try to do a lot of things and try to find out a lot of things to create a holistic image. But there are still many, many more aspects which we might not have in mind. For example. Earthquakes in Bangladesh. Nobody talks about earthquakes, but it's an earthquake prone area. So, every 100 to 120 years, there will strike an earthquake and Dhaka will be damaged completely with 15 million inhabitants. Nobody talks about it, but it will happen. I'm sure I'm not a prophet, but geology geological records tell us. So, there is no intense public discussion about the Asian dust. We have talked about brick kilns. In Bangladesh, for example, or other Asian countries, they set free enormous amounts of dust. They burn everything. They burn car tires. They burn. So, they have reduced surface temperatures dramatically in and around major Asian cities.

So where is the truth? You have to put so many aspects together that even for me as a scientist who tries to figure out what is going on there. I don't know. I have only fragments. There is no reality which we can really honestly try to say that we know the reality. This is not possible. And this is a serious question. What we can do is we can try to discuss aspects. We can try, for example, dust emissions by brick kilns because they burn car tires just to. So, we can say, okay, this is not really healthy. It's not good for your lungs. And if it's not good for the lung, lung cancer and other aspirational diseases are developing very fast in Asian countries. And you can say, okay, this is and we do not talk about the atmosphere. We do not talk about climate change, but we talk about health here and ... Arsenic contamination of soils in downstream countries in the Himalayas. So, I have no answer. There are thousands. If you look at systems and cycles, there are thousands of small elements which you should have taken into account. It is not possible. And there is no answer to your question. Maybe this is the best answer to teach the people that it's much more complex. Yes. Then they might think. And therefore, it is something you might not want to hear. Yeah. **Q:** The second thought with Sparkles is that as a computer scientist, you have big data. You have lots of data. You can measure the data. You can show IoT sensors to do that. You have AI to process the data. So, this might be one direction to go for to say, like, it's complex. It's maybe even total chaos. And we can throw all tools on it to possibly get more insights and use them. Yeah. That would be helpful. So that's one approach. One comment on this. That's the core of the best here. And that's also the wish, the fundament for the best. Now, only this morning we had two key world class pillars for the challenges and for potential solutions, physics and the life span, and most of Mother Earth, the trust in science. We believe in the people as well, in their smartness. And Professor von Weizsäcker's keynote yesterday about collaboration and trust, sustainable collaboration seen internationally. And the other very important keynotes, knowledge transfer, the collective intelligence, innovation perspective, only to mention a few. So, these pillars, these really promising pillars, they give us education and research, transformation for the industry, and of course political and all other dimensions. Hope in

Immanuel Kant. That we act as a humanity with reason. And that gives us all hope that it can be achieved. A better world for all of us. All the responsibilities.

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