Nitrogen, Agrochemical Corporations, and International Trade: A Perilous Mix

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Gilles Billen (GB): My talk is about the challenges of feeding Europe and the world in 2050. By that time the world population will have increased by 2 to 3 billion inhabitants before just stabilizing at that level. These additional people to feed is not in fact the main challenge for feeding the world. The main challenge is related to the effect modern agriculture already has on the environment today. You probably already heard about the planetary limits. These are threshold values of some indicators of human activity beyond which the habitability of Earth is compromised. And six over nine of these planetary boundaries as defined by Rockstrom are already crossed. And modern agriculture has a big part in this crossing. Agriculture is producing about one-third of the greenhouse gases. So it's largely responsible for climate change. Agriculture is responsible for most of the loss of biodiversity. And agriculture also is responsible for a complete overhaul of some nutrient cycling, mainly nitrogen cycling. I just want to insist a little bit on this aspect.

Lynn Fries (LF): Hello and welcome. I'm Lynn Fries, producer of global political economy or GPENewsdocs. Today's guest is Gilles Billen. Some of his recent comments of relevance to today's conversation were featured in that opening clip.

Gilles Billen will be talking about a biogeochemical view of the historical trajectory of regional and global agro-food systems and from there an alternative at the global scale and the European scale. The European regional example being a case in point of how regional agro-food systems have become tightly integrated into international food and feed trade networks. A system in which world trade of agricultural commodities when seen from a biogeochemical perspective is net exchanges of proteins among 12 interconnected regional agro-food systems that taken together make up the global agro-food system. Here to explain what all this means and what it has to do with feeding a growing world population without exceeding safe Earth boundaries is Gilles Billen. He joins us from Paris where he is Emeritus

Research Director at the National Center for Scientific Research (CNRS) and Senior Researcher in Biogeochemistry at Sorbonne University. Welcome, Gilles.

GB: Thank you.

LF: As a unifying metric, you put nitrogen at the core of your analysis of agro-food systems. As put in your recent report, *Beyond the Farm to Fork Strategy*: "Nitrogen (N) is at the heart of the debates on the socio-ecological transition of agro-food systems for several reasons, relating to human nutrition, agricultural productivity, ecosystems functioning, and planetary boundaries". So start there, explain that. Why nitrogen?

GB: Why not nitrogen? Usually most people are taking the subject in terms of one other metric which is calories. Calories are indeed, the metric that is used by dietitians to calculate the diet of people. But, in fact, nitrogen is as important as calories. Nitrogen is the main component of proteins. And proteins are really what we need for building up our tissues. Calories are a source of energy just to compensate for the exercise. But really, proteins are needed at a rather constant amount per day for any individual independently of the exercise he's producing in his everyday life. So, this amount of about 10 grams of protein per capita per day is the required amount for everybody. And on this basis, you can calculate the amount of nitrogen in proteins required annually for a given population. And this is 4 kilograms of nitrogen per capita per year. And this is a very important figure because it gives you the objective of agricultural production. You need to produce 4 kilograms per capita, per year of food for feeding the world. And that's all. And it is convenient also to calculate this diet in terms of nitrogen because you can compare it directly with the fertilizers, generally speaking, needed to produce agricultural goods. Nitrogen is among the different fertilizers used in agriculture. Nitrogen is also the one which is the most limiting, generally.
Nitrogen is paradoxically a very rare element in the soil. Although there is plenty of dinitrogen, gaseous nitrogen, in the atmosphere, this form of gaseous nitrogen is not available for plants or most plants. So that in fact, nitrogen is limiting for the growth of plants. And fertilization is mainly a way to add, to bring nitrogen to the soil in order to maintain the fertility, to maintain the possibility of plants to export nitrogen with the harvest.

And so nitrogen is really the most convenient metric to calculate what the world has to produce from its agriculture to feed the world. That's the reason why we are interested in nitrogen. Besides that nitrogen is also one of the elements for which the natural cycle has been disturbed the most by anthropogenic activity. So there are planetary boundaries linked to the cycle of nitrogen and we should stay behind these planetary limits in terms of nitrogen. So, these are the different reasons for which nitrogen is probably the best metric for discussing all that.

LF: In your comments you touched on the paradox of nitrogen. What do you mean by that?

GB: Well, as I said, nitrogen is a very essential component of living organisms. So, it is contained in proteins, also in nucleic acids, and things like that. So, it is essential to life. The

organic forms of nitrogen are linked to the very structure of living organisms. Besides, there are inorganic forms of nitrogen such as nitrate, ammonia, nitrite also. Most of the inorganic nitrogen on the earth is nitrate. But this is nothing compared to the amount of nitrogen which is the main component of the atmosphere. Everybody knows that the atmosphere contains nearly 80% of the gaseous nitrogen N2 which is a very inert gas; besides that there is 20 percent oxygen. In fact, we are swimming in an ocean of nitrogen but under a form that cannot be used to make up our tissues. Animals eat proteins from the plants they are eating. And we are also eating proteins from our vegetable or animal food. But the primary production of organic matter is based on the uptake of inorganic nitrogen forms, nitrate or ammonia, by plants.

Plants generally can only use either nitrate or ammonia. And these chemical forms of nitrogen are in very small amounts in the soil. So that each year after the harvest of a field has been taken off from the field, the soil must be replenished with new nitrogen in order to make the further growth of plants possible. Recycling of nitrogen is therefore of primary importance for ensuring the fertility of soil. And okay, this can be by recycling. Indeed excrement or urine or our feces and those of animals are full of nitrogen which has to be brought back to the soil in order to guarantee the fertility of it for the next year.
However these inorganic forms of nitrogen, particularly nitrate and ammonia, are very mobile. Ammonia is very mobile because it is a gaseous form which can escape to the atmosphere. Nitrate is very mobile because it is very soluble and any rain draining through the soil profile takes off large amounts of nitrate if some remain there after the growth of plants.

So, these losses or the lack of recycling of nitrogen has been to be compensated by new imports of nitrogen. In natural systems, these new inputs of nitrogen are done through a very exceptional process which is symbiotic fixation by legumes plants. Legumes like clover, alfalfa or lucerne, beans, lentils. All these plants, which are called the legumes, have the capacity owing to symbiotic association with a special group of bacteria to transform this N2 molecule (the gaseous nitrogen of the atmosphere) into reactive forms into proteins in fact), into reactive forms of nitrogen. And only this group of plants is able to do that. So that, in fact, in natural systems these losses, these unavoidable losses of nitrogen due to leaching, due to volatilization have to be compensated for by the activity of this group of plants. And that's okay, in a forest, you have some amount of nitrogen coming back to the atmosphere or leached to the aquifers but this is compensated for without difficulty by the few legumes occurring in the community of plants in a natural ecosystem.

This can also be the case in agricultural systems. In traditional agriculture there is always an association of plants with one year cultivation of clover, for instance, to feed animals, and then cereals and then another plant. And this rotation of plants ensures that there is enough nitrogen taken from the atmosphere by legumes to ensure that with an efficient recycling of manure and even human excreta, the fertility can be maintained. Once you have very specialized agriculture, like monoculture of cereal, for instance, you have no way to get this new nitrogen necessary to do the fertilization and you have losses that you cannot

compensate for. And that's why, in fact, this kind of very specialized agriculture is only possible owing to industrial fertilizers.

Industrial fertilizers came in use only from one century ago, in fact. Two German chemists, Fritz Haber and Carl Bosch at the beginning of the 20th century, 1909, discovered the way to fix atmospheric nitrogen into reactive nitrogen, into ammonia and nitric acid. Their purpose was to make explosives. At that time, that was the problem, finding enough nitrate to make explosives. And this was close before the First World War. This process requires lots of energy from coal at that time, now from either petroleum or natural gas. But this process of fixation of atmospheric nitrogen into reactive nitrogen allowed it to make chemical industrial fertilizers which are used in place of legumes or in place of a correct recycling of manure or human excreta.

And so, modern agriculture is largely dependent on these synthetic chemical fertilizers which has disturbed the nitrogen cycle. Imagine that today more than half the amount of nitrogen put into the biospheric cycle is from industrial activity. So, in fact, humans have doubled the amount of nitrogen introduced into the biogeochemical nitrogen cycle. And that's a major perturbation which allowed an explosion of the environmental losses of nitrogen to the atmosphere, to the hydrosphere; massive contamination of groundwater, massive contamination of the atmosphere, and so on.So this is a major disturbance due to this fantastic recourse of industrial fertilizer which allowed to get rid of this obligation that traditional agriculture had in the past to alternate legumes and cereals. And ensure that legumes bring back the nitrogen required for ensuring the fertilization of soils.

LF: The use of industrial fertilizer produced under the Haber Bosch process made it possible for modern agriculture to put an unlimited supply of reactive nitrogen into the soil. So, modern agriculture became highly specialized. With this, as you say, modern agriculture is dependent on industrial fertilizers which has disturbed the nitrogen cycle. Give us more context on this issue with the nitrogen cycle.

GB: Nitrogen is not abundant in soil. Plants use lots of it to grow, just to make its tissues. After one harvest, the soil is depleted from this element, nitrogen. So, in order to make a new harvest possible the year after, new nitrogen has to be brought into the soil. And this is fertilization, in fact. Fertilization can be just the recycling of the excrement of those animals or humans having eaten the harvest and that has closed the cycle, except that there are some losses in between. Or it can be brought by new nitrogen. This new nitrogen, well, it's not just recycling, it has to come from elsewhere. This elsewhere is usually the atmosphere. Some plants can bring new nitrogen from the atmosphere by the natural process of symbiotic fixation. Legumes do that perfectly and have done that for millenaries on the Earth. Industry can do that also and that's the chemical fertilizer

Some opening of the nitrogen cycle always exists at different degrees. It always exists because of this mobility of nitrogen. Some environmental losses of nitrogen always happens. But the opening can be just organized because recycling is no longer necessary. So

specialization of agriculture into only cereals, for instance, this kind of very specialized system is a complete opening of the system. And so synthetic has to be used as the only way of fertilization.

LF: So under this specialization of modern agriculture, synthetic or industrial fertilizer has to be used as the only way of fertilization because processes of recycling and symbiotic fixation by legumes done in association with nitrogen fixing bacteria in the soil, as you explained, have been eliminated. So let's back to the point you make that since the use of industrial fertilizers there has been an explosion of environmental losses of nitrogen. Talk about those losses.

GB: Well, insofar as synthetic fertilizers are now representing about half the total amount of fertilizing inputs to the soil, they have increased tremendously the losses, the environmental losses of nitrogen. And these losses are just not losses; in fact, they are causing trouble. They are causing trouble to the hydrosphere. When you have nitrate draining to groundwater, the usual reservoir for drinking water, the possibility of using this water for drinking water is completely lost. So, this is one problem.

Another problem is that this nitrate rich water flowing from groundwater to rivers and then to the sea are, in a way, enriching the sea. In coastal waters, in coastal marine waters, nitrate is also a limiting nutrient for algae. And algae are growing much more when rivers rich in nitrates are coming into those coastal zones causing a process of algal proliferation, which in itself can be a problem. In France we have this problem of green algae accumulating on the beaches. But there are many other problems. On the coast of the North Sea, some algae are producing mucus and make foam. Other algae are producing toxins. Also sometimes this enormous algal biomass is coming down to the deep zones of the seas and decomposing there forming anoxic areas which are called the dead zones. All these processes which are grouped under the term of coastal eutrophication are destroying, in fact, the capacity of coastal zones to produce fish. So there is a big eutrophication problem linked to this massive use of chemical fertilizers.

We can also speak of the atmosphere, that's a little more complex. Ammonia which is escaping to the atmosphere may react with another pollutant which is not from agricultural origin, nitric oxide produced by electric centrals or combustion motors, automobile motors. And this urban pollution meeting the rural or agricultural pollution by ammonia form together ammonium nitrate, very small particles. And these particles are responsible for a big part of air pollution. So air pollution is a consequence, partly at least, from agriculture, from industrial agriculture. Another very important thing is that also part of these atmospheric losses of nitrogen are under the form of N2O nitrous oxide which is the second important greenhouse gas after CO2, after carbon dioxide. And so, these environmental losses of nitrogen also increase the warming effect, the greenhouse gas effect. For agriculture, N2O is one of the major greenhouse gases produced and that's again a consequence of the use of industrial fertilizers.

LF: So just to be clear, the environmental nitrogen loss you have been talking about refers to the amount of nitrogen that instead of being taken up by plants and converted into food is being lost to the environment. What your research shows is more than half the input of synthetic chemical fertilizer is lost to the environment.

GB: Absolutely. Because of this very bad efficiency of recycling caused not only by the use of chemical fertilizers per se but by the structural opening of the cycle that this use makes possible.

LF: In a recent article published at The Conversation, you explain agricultural nitrogen surplus is the excess of nitrogen put into the soil in relation to the quantity actually taken out of the soil through harvesting. And this excess as you have been explaining. can turn into run off and drain into the Earth's water systems. It can turn into gas and enter the Earth's atmosphere. And what's called nitrogen waste is the nitrogen surplus not utilized by crops. As context to all this, I want to go back to a point you made at the open: that planetary boundaries are linked to the nitrogen cycle. And to briefly cite your article: "That is why the team working under Rockstrom evaluated the agricultural nitrogen surplus when defining the planetary boundaries beyond which conditions for human life on Earth would no longer be guaranteed. The upper limit of this surplus, which is determined to protect water and air locally, varies greatly between world regions, but on a global scale it is estimated to be 60 million tons of nitrogen per year, in contrast to today's nitrogen surplus of around 130 million tons of nitrogen per year. This huge gap between the threshold not to be overstepped and the actual level reached today justifies the goal that the European Commission and the United Nations' Biodiversity Conference recently set itself to halve nitrogen waste by 2030. Yet it is not by simply adjusting practices that nitrogen waste from agriculture will be halved so that the planetary boundaries are respected. Industrial producers of fertilizers promote the progress offered by precision agriculture, nitrification inhibitors applied to the soil, varietal improvement of crops, and so forth. These new methods that promise progress might open up lucrative markets for the agriculture supplies industry, but everything else points to them bringing only a negligible drop in nitrogen waste. Indeed the most effective way to boost efficiency and reduce loss is to scale down agricultural production itself!''

Can you explain what structural changes you have in mind in making the comment that "modern agriculture's bad efficiency of recycling is caused not only by the use of chemical fertilizers but by the structural opening of the cycle that this use makes possible and also the comment that it is not simply by adjusting practices that nitrogen waste from agriculture will be halved.''

GB: Okay, there are two aspects of these structural changes. The first one is, we already spoke of it, is specialization. What is striking is that when you look at the structure of our agriculture at the regional scale, everywhere in Europe particularly in France, but everywhere in fact, you have regions specialized into intensive cereal cropping without any animals. And so that's a very linear cycle where you put fertilizers and you harvest cereals and that's all. In other regions, you have all the animals grouped. And in this region, the agricultural

production is not enough to feed these animals which are very concentrated. So you have to import feed for these animals. And they are producing manure which cannot be used for recycling, for fertilizing the field because they are producing too much amount and so they are leached. So this structural specialization into either livestock farming or crop farming is the cause of enormous environmental losses of nitrogen. That's one aspect.

The second aspect is that we have increased tremendously the intensity of agriculture. Agriculture is producing per hectare, per hectare cropland, much more than it did before. You may say: okay, but that's because the human population has increased tremendously too. And we have to continue this movement because the human population will reach ten billion inhabitants by 2050. And so you can say there is no alternative compared to this increase in productivity. But, in fact, when you are looking at the fate of crop production nowadays, it is for more than 70% just to feed animals. We are producing cereals and other feedstuff not to feed humans, but to feed the animals that humans will eat. What has increased the most is the production of crops for feeding animals which are converting this production into meat and milk, but with very bad conversion efficiency. Because okay, the efficiency of conversion of vegetal proteins into animal proteins is at most 30%. And that's in the most intensive livestock systems. Most of the time it is much less.

Why is that?Why do we feed so much to animals? It is because, at least in most Occidental countries, the share of animal food has increased tremendously. In the United States, in Europe, about 70% of the proteins taken up by humans are of animal origins while it was about 30 percent in the 1960s. So, in less than one century, we increased by a factor of two the share of animals in our food. And that is accompanied by a need for feed production, including cereals. That is the most important factor of the increase of agricultural production. It is not to feed people that agricultural production has increased so much. It is mostly to feed more animals. And okay, and that's not needed at all. It is even bad for health. There are many public health problems linked to this increase of animal food in our diet.
I am not at all saying that we should be vegetarian. Animals are a very good way to convert some proteins which exist under forms that are not edible by humans, to convert this kind of protein into edible proteins like milk and meat. But once you are feeding animals with proteins under forms that are directly edible by humans, you are wasting completely a resource.

LF: Give us more context on how in the post World War II era, local and regional agro-food systems throughout the world lost regional self-sufficiency and so autonomy and through a process of globalization and regional specialization became integrated into international food and feed trade networks. Europe as you say is an example of this. So tell us something about your analysis of the European agro-food system and from there the alternative you explore in your agro-ecological scenario at the European scale and global scale respectively.

GB: Historically, the beginning of this process of modernization of agriculture at the European scale was to get Europe self-sufficient in food production. And so there was good reason to try to get to self sufficiency. But this process of modernization went hand in hand

with an opening. The purpose of the agricultural policy was really to make Europe an exporting country much beyond reaching self sufficiency. And okay, and from that time on, the pursuit of an objective of exportation by increasing productivity by specializing agriculture and by also using more and more chemical fertilizer became the first objective. Suddenly, we realized that we are importing enormous amounts of synthetic fertilizer from outside Europe, in fact. Because fertilizers contain so much energy that only countries with large reserves of fossil energy are producing them and exporting them. Russia, Algeria, and the countries of the Middle East and so on. So in fact, Europe is extremely dependent on external resources, inputs of fertilizer.

So, okay. Could Europe make it without fertilizer? Could the world make it without Haber Bosch fertilizer? You probably know about *Our World in Data*, that's a website produced by Oxford University. And they have a visual about Haber Bosch fertilizers, showing how much people in the world are depending on Haber Bosch fertilizer just for their food production. What the visual shows is that half the population of the world nowadays depends on Haber Bosch fertilizer for its food production. That's a matter of fact. What they conclude in the site is that Haber Bosch, the invention of the Haber Bosch process, saved half of humanity. That 5 billion people would have died without this invention. Which is absolutely not true, of course. If this process hadn't been invented, well, agronomy would have developed a better way of using legumes, a better way of reconnecting livestock and crop farming. And we could have also made the life of 10 billion inhabitants, of at least 8 billion inhabitants in the world possible. That's just another structural way of organizing organic agricultural production.

And so what we explored in our scenario, both at the European scale and at the world scale is can this be possible? Can we indeed feed 10 billion inhabitants of the planet in 2050 without any recourse to synthetic fertilizer? And by operating three levers, we showed that it should be possible. First lever is generalizing this crop rotation, this traditional crop rotation, in fact, where legume alternates with cereals to make new inputs of nitrogen possible. Second lever, reconnecting livestock and crop farming in order to better close the nitrogen cycle at the regional scale. And the last lever is the one of the diet, reducing by at least a factor of two, the share of animal proteins in the human diet. And with these three levers, we show that it is perfectly possible to imagine a future for agriculture, both at European scale, where we did it at very small scale, and at the world scale, where we did it just for 12 regions in the world. We show that it should be possible. The range of possibility exists that we can feed all people on the planet without any of this fertilizer. Okay. And the demonstration, I think, is rather convincing.

LF: So what you show with your agro-ecological scenario is that it is possible to meet the challenge of feeding all people in the world and halve nitrogen waste and greenhouse gas emissions from agriculture by 2050.

GB: Exactly. Because all these levers I talked about reduce environmental losses of nitrogen. It reduces them for structural reasons, in fact. It reduces them because symbiotic fixation is a

much more efficient process than application of chemical fertilizer. Because reconnecting livestock and crop farming also reduces the losses because the recycling is much better organized. And reducing the amount of animal proteins in the diet doesn't require as much intensive crop production than today. And also, by reducing the intensity of agriculture, you automatically reduce the losses of nitrogen. Intensification of the production is the main cause of nitrogen surplus which is the cause of leaching and environmental losses. So, by reducing the intensity of agriculture, you automatically reduce the environmental losses. That's why; you might respect the planetary limits which are about losses.

LF: In commenting on rising environmental losses of nitrogen and rising international trade in agricultural commodities, you present a visual of the trajectory of the world agro-food system from 1961 to 2009 to 2050. And again using nitrogen as a unifying metric expressed in millions of tons per year, in this visual agricultural nitrogen loss to the environment is represented on the vertical axis and trade, international trade of agricultural products, on the horizontal axis. From 1961 to 2009 being the actual recorded past trajectory of the world agro-food system and from 2009 to 2050 being a projection for the future trajectory of the world agro-food system based on a business as usual scenario to 2050. What the visual shows is that under a business as usual mainstream scenario, the past trajectory of rising environmental losses from 1961 to 2009 continues to 2050. So in short, what this shows is that in the absence of significant change in the structure and operating logic of modern agriculture, so business as usual, the past trajectory of rising environmental nitrogen losses continues unabated. I am going to put up another visual in which you compare the business as usual scenario which in this visual is called the conventional agriculture or 2050 Global Orchestration scenario to that of the agro-ecological scenario called the 2050 Equitable Diet.

The agro-ecological scenario shows that it is possible to reverse course from the past trajectory of rising environmental nitrogen loss recorded from 1961 to 2009. This scenario shows environmental nitrogen loss and large disparities in regional diets can both be dramatically reduced by 2050. In contrast, under the business as usual scenario both environmental nitrogen losses and large regional disparities in diet continue on a rising trajectory to 2050. In this visual you call the agro-ecological scenario the Just Diet scenario. Why's that?

GB: We call that the "Just Diet" or the "Equitable Diet" because it's a diet that can indeed be shared with all the inhabitants of the planet. In most scenarios run by economists you still have lots of inequalities in the diet between the different parts of the world. Because they consider that there is a constant and unavoidable link between the monetary richness of a country and the diet of this country. Indeed, this relationship is apparent when you look at the statistics. The more the PIB (Produit Intéreiur Brut/GDP) is high, the more you eat meat and milk, but is that really a law of nature? I don't think so. It's not just a question of availability, it's also a question of health, and eating less meat is certainly, less meat and less milk is certainly not a punishment. I mean, it's also the way to maybe avoid coronary diseases and lots of other diseases. So, well, it can be a choice, a voluntary choice.

LF: To round off on your business as usual and agro-ecological scenarios to 2050, the results you show at the global scale are also reflected in your findings at the European scale. Where in addition in a third scenario, the Farm to Fork scenario, you show the European Commission Farm to Fork strategy does not meet its objectives. The upshot being only the fully agro-ecological scenario meets the European Commission goal of halving environmental nitrogen waste.

That's because your Farm to Fork scenario was based on and so named after the European Commission strategy to meet their objective of cutting nitrogen waste in half, the EU Farm to Fork strategy. How do you explain that disappointing result of the Farm to Fork strategy?

GB: Well. They do not go far enough, that's all. The intention is good but the way they are proposing it does not go far enough to reach these objectives. And this Farm to Fork Strategy is attacked very violently by lobbies.

LF: Let's bring international trade into the picture, specifically international trade in animal feed. As you say agricultural production has increased so much not to feed people but to feed animals and this has been accompanied by massive trade in animal feed. And again from a biogeochemical view, world trade in agricultural commodities, like animal feed, is net exchanges of protein, so nitrogen between 12 interconnected regional agro-food systems which taken together make up the world agro-food system.

In the historical trajectory of regional specialization under globalization, in the Global South many developing countries integrated into international food and feed trade networks as massive exporters of animal feed and subsequently rely heavily on this trade as a source of export earnings. Meanwhile, big agribusiness interests have been empowered by this export trade. Geopolitics aside, the biophysical reality of all this has to do, as you say, with the effect of modern agriculture today on the environment and so the nitrogen cycle and planetary boundaries linked to the nitrogen cycle. The point being the intensive agricultural production of animal feed in the Global South has huge environmental consequences, most notably deforestation. On the other side of this trade in the international food and feed trade network are the regional agro-food systems which as you show are heavily reliant on imports of animal feed. You gave us some context earlier on how Europe as a regional agro-food system became heavily dependent on enormous amounts of external inputs from outside of Europe. At present, as your report *Reshaping the European agro-food system* details, livestock consume 75% of Europe's crop protein production in addition to 2.7 million metric tons of nitrogen per year in imported feed, mainly maize from the US and soybeans from South America contributing to deforestation.

Your agro-ecological scenario at the European scale shows it is possible for Europe to feed its population without importing animal feed and so without contributing to deforestation in the Global South. At the global scale, you show there is vast policy space to feed the world without deforestation. As historic context to all this, talk about what you see as three international food regimes with the 3rd being where we are today. So start by talking about

the read through you see from the first international food regime to the present 3rd international food regime.

GB: There is this first international food regime which is the beginning of the free trade for agricultural products**.** The first food regime in the 19th century was driven by another pioneer front. It was, in fact, the cultivation of the great prairie, the American great grassland area of the US Midwest which was a way to produce a huge amount of cereals which were exported to Europe. And England based all its policy, its imperial policy, on delegating its food production to its colonies or former colonies by initiating a massive global trade of agricultural products. And the main source of food was this exploitation of the pioneer front of the West region of America. The duration of that was about 30 years, 30-40 years. After that the soils were completely depleted of nutrients. And the yields were very high there because there has been for millenaries this herbaceous formation with only buffaloes grazing on it. And, okay, but this was completely exhausted.

Well, and what is happening in Brazil and also in Argentina nowadays is exactly the same thing. The pioneer fronts are there now in Latin America. And so these massive imports of soybeans from Latin America is the result of the soil exploitation of a pioneer front. A new pioneer front, the last one on the planet probably, that will be destroyed in a few decades. So, we cannot really make plans about the capacity of these countries to continue their massive export of soybeans and other feeds.

LF: In a nutshell, what big differences mark these 3 international food regimes?

GB: In the first regime, England and most European countries decided to delegate their food production to others. In the second food regime, the states came back and organized their own production and the modernization of its production including the Green Revolution and so on. So they imposed the use of Haber Bosch fertilizer as a normal way to run agriculture but there was a very strong state control of agriculture.

The third food regime from the 1980s, more or less, is characterized by a general policy of of neoliberalism which means that the state is just letting firms decide what is good or not because the firms are closer to the market and the invisible hand of the market will do things much better than the state can do. Oh yes, there are regulations. There are state measures taken but most of the organization at the world scale is the one that firms, international firms, are deciding. And that’s a big difference.

LF: So having been convinced the use of industrial fertilizers was the only way to feed the world, the Haber Bosch process and the Green Revolution was imposed in the 2nd international food regime under strong state control of agriculture by governments. You give the US Marshall Plan for Europe as an example of the kind of strong state leadership you are talking about. Consistent with this, the 1947 GATT, the General Agreement on Tariffs and Trade, agriculture was excluded from this original UN multilateral trade agreement. As we all know this changed in the 3rd international food regime as free trade in agriculture was

brought back into force with the creation of the World Trade Organization. Plus intellectual property rights over agricultural products like chemical fertilizers and other proprietary technologies gained protection under international law as the WTO replaced the GATT in the UN multilateral system of trade. And with this agro-food systems became interconnected through international trade. The logic then of regional specialization seen in the first international food regime which was the beginning of free trade for agricultural products resurfaced in the 3rd international food regime.

GB: Yes, David Ricardo at that time was explaining that countries have always had an interest to specialize production and organise exchanges with others. So, free trade is always better than autarky. That was the dogma of David Ricardo. That's the basis of neoliberalism. And everybody continues to think with this same idea that free trade is better than autarky of both parties. But this is not true. And this is not true if you are looking at environmental consequences at least. Specialization is the consequence of free trade; specialization is the cause of the opening of material flows; the opening of the cycles of nitrogen and other substances. So, free trade is really at the core of the environmental problems we have today. And that is particularly true for nitrogen.

LF: Earlier you said the post on the *Our World in Data* site claiming that the invention of the Haber Bosch process had saved half of humanity was absolutely not true. That if the Haber Bosch process had not been invented, agronomy would have developed a better way of organizing agricultural production. So a better way of using legumes, a better way of reconnecting livestock and crop farming. Instead what happened as you write in your report *Reshaping the European agro-food system* was that very few public resources were invested in the development of more sustainable agro-ecological options such as those you expose in your report. In spite of decades of massive underinvestment, history tells us these systems have proven extraordinarily resilient in feeding their populations without ruining their regional ecosystems or crossing the Earth's planetary boundaries. You point to significant upside potential yet to be tapped.

As put in your *Farm to Fork* report, quote: "There is quite a lot of diversity of agro-ecological systems worldwide, as these are based on subtle mix and exchanges of farmer and scientific knowledge strongly linked to territorial peculiarities. Moreover the innovation capacity of farmers is an important aspect for the adaptability and performances of these systems in a changing world." Given everything we have been talking about, where do you think all this leaves farmers?

GB: The possibility is vast. The range of possibilities is vast but the ability to act is very locked. That's the problem. The actors locked the system in the way it is now. And changing it to a much better, much better organization is difficult because of this locking. The power of deciding farming activities is no more in the hands of the agricultural people themselves.There is what is sometimes called an asymmetry of power. The decision making power is no more at the farm level. It is upstream, the big producer of fertilizer, of seeds and so on, of pesticides also. And downstream, the big actors for transformation and retail. So the

margin of decision making of the agricultural people, of the peasants, in fact, there are no more peasants, but the agricultural people are very limited. And they just make what the rest of the actors are expecting from them. And that's also why it is very difficult to make these structural changes operate at the farm level except outside this big network of actors. Organic farmers, for instance, can construct a new network because they are much less dependent upstream and downstream from the big actors. But they are also dependent on the market, at least on the consumer's choices and so on. So, it's becoming very difficult indeed to, to change something in this very globalized organization of agriculture at the world scale.

In France, it's incredible the most important organization of farmers which is the majority syndicate for agriculture is directed by the director of the biggest industrial food production system. The representatives, the political representatives of agriculture are, in fact de facto, the defenders of the industry. There are farmer's organizations, citizen organizations struggling for new organisations. There is a project, for instance, in France, but also elsewhere in Europe I think, of securité sociale alimentaire, food social security, organized collectively in the same way as healthcare. We have the example of the health policy that was put in operation in the 1950s everywhere in Europe, nearly, in different ways. But, okay. Why couldn't such an organization be possible for agriculture and food production?

LF: This conversation has gone a long way towards explaining your position that as you put it: "We need to stop assuming that the only way to meet the planet's growing needs in food is continued intensification of industrial agriculture, continued specialization in agriculture and continued growth in international trade of agricultural products. On the contrary, this model of agriculture has now been clearly identified as a factor that disturbs the Earth's system profoundly. We will only be able to feed tomorrow's world, while respecting the conditions for life on Earth, by making major structural changes to the global agri-food system based on frugality, reconnection and agroecology.'' As we conclude, what message do you want to get out there?

GB: Well. I would say another world is possible. It's not necessary that we produce more and more. The fact that the world population will still be growing by 2 billion before stabilizing, because that's a fact, this does not justify at all that we intensify more and more the production. It is not necessary that new technologies like precision agriculture, drones everywhere, satellites and so on, it is not necessary to have these new technological tools at hand for making agriculture less polluting. We just have to reorganize, to restructure agricultural production by looking first at regional needs. Self sufficiency is not always possible. In all territories, it's not possible. But when it is possible, it should be an objective. Taking into account that some regions will need international trade but international trade of food is not an objective in itself. Looking first at self-sufficiency, organizing agriculture on a territorial basis is the best way to achieve an agricultural production which respects the planetary limits and the environment. That's the message, in fact. And that is just a question of organization. It is not a question of new technologies. And intensification, increase of production, is certainly not required for feeding the world. That should be the message maybe.

LF: Gilles Billen, thank you.

GB: Thank you.

LF: And thank you for joining us.

END

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