And so welcome everyone to today’s seminar, hosted by the Yale Center on Climate Change and Health.

So, I’m Dr. Kai Chan, Assistant Professor of the EHS Department. I’m also the Director of Research for the center. So today, we are very honored and prepared to have Dr. Lewis Ziska come to give us today’s lecture. So Dr. Ziska is a professor at the Mailman School of Public Health at Columbia University. Before joining Columbia, he was a senior scientist at the US Department of Agriculture for nearly 25 years.

So he’s one of the most leading experts on the effects of climate change on plants and agriculture.

So, without further ado, let’s welcome Dr. Ziska. (students applauding)

Thank you, Professor Chan, I appreciate the opportunity to be here. The good news is you’ve got free food. (students laughing)

The bad news is you’ve got to listen to me lecture so... The wanted to look at the nexus between climate change, rise in carbon dioxide and public health and just sort of give you a sense of the range of different consequences associated with it. So we have the good, we have the bad, and we have the OMG.
So, I want to go through and talk about some of the work that we’ve been doing on all of these different aspects. Before I do that, however, I wanna make sure that we’re all on the same page when it comes to defining what we mean by climate change. So, we know that carbon dioxide is going up. This is a recent Keeling Curve, where you can see that we’re getting close to about 410 parts per million. In my lifetime, the amount of carbon dioxide is increased by about 30% and the reason why is not difficult. It turns out that if you take a carbon source, fossil fuel source, and you oxidize it, you burn it, carbon-oxygen, yeah carbon dioxide, who knew? So, if you look at, this is a little bit out of date, but if you look at where the carbon dioxide comes from, again, oxidation of fossil fuels and cement production in calcium carbonate, one of the offshoots of calcium carbonate is carbon dioxide. Land use change, where does it go? About 50% of it stays in the atmosphere, about 25% of it goes back in the land through photosynthesis, and about 25% of it is dissolved into the oceans where carbon dioxide and water is formed (mumbling) acid. Okay, so... here are as we know, this particular change is recent. This is the highest carbon dioxide that we’ve experienced, at least in the last million years.
We know where it comes from, where is it gonna go? Well, depends on which model you happen to believe in.

And I won’t go through all the different models. We’ll look at the green one down here. We’ll call this everyone drive a Prius and Hans model, and that so far is not working out. We have the business as usual model here, and that may not be working out because that’s depending on a certain amount of coal usage, and that’s been going down, but there’s still a bit of uncertainty about the fact, particularly in regards to methane, but there’s no question that it’s going up. If we just do the rule of thumb, it’s going up two to three parts per million per year. We have about 80 years left, so it can range anywhere from 160 to 240 parts per million higher than it is today. Okay, so why should you give a flying fig whether carbon dioxide is 300 or 400 or 500, what difference does it make, right? Well, it makes two differences.

The first one has to do with the physical aspects of increasing these particular gases. We know that the atmosphere consists of certain gases. Most of those we are familiar with, but there are two that we consider to be global warming gases. What does that mean exactly? What makes it a global warming gas?
I will, of course, turn to music.

How many of you have ever played a string instrument?

Excellent, so I’m gonna turn this over to you.

Suppose for the sake of argument that I tune two strings to the same frequency, okay?

Let’s say A 440 Hertz, all right?

So you have two strings that are tuned to the same frequency, and I pluck one string, what will the string next to it do?

Suddenly vibrate?

It’ll vibrate, it’ll resonate, it’ll absorb some of the energy from the first string.

What if I’m a Methodist, will that still work?

Yes.

What if I’m a republican?

Yes.

Are you telling me that the laws of physics are independent of religious denomination and political affiliation?

Oh my god, you have no idea.

So, what does this have to do with being a global warming gas?

Well, it turns out that in addition to music, molecules also resonate.
but they resonate in the key of infrared, or heat.

So whenever heat is experienced by one of these molecules, it resonates, it absorbs some of that energy that would otherwise be lost, does that make sense?

Good, this has taken an entire semester of physics and atmospheric chemistry into five minutes so please forgive me.

So the two major greenhouse gases are carbon dioxide and water vapor, humidity, if you will.

All right?

So as this change in carbon dioxide occurs, that’s not a bad thing because there’s a natural greenhouse effect.

If there were no carbon dioxide, the average temperature on the earth would be about minus 80 degrees Celsius. So, by having carbon dioxide, by having water vapor, you have a livable environment.

But I think you can see that this sort of a Goldilocks principle that occurs here, right?

Too little, too much.

So, we’re seeing the earth warm up, but it’s not warming up the same everywhere, is it? Some areas are warming up faster than others.

Why?

Well, if it was the sun, then the equator would be warming up very fast. It’s not, what’s warming up the fastest?

What area of the world is warming up quickly?
The poles. The poles.

They get the least amount of sun, how come they’re warming up so quickly?

Wait a minute, I said there were two, there were two greenhouse gases, weren’t there?

And, water vapor’s one of the greenhouse gases, so where on the globe is water vapor dominant, the dominant greenhouse gas?

Where’s the air warming unit?

I’m not trying to trick you.

At the equator.

So at the equatorial regions, where it’s warm and wet, you already have water vapor, it’s the dominant greenhouse gas.

Adding more CO2, yeah, it’s gonna get warmer and wetter.

Is it gonna rise very quickly?

No, it takes a lot more energy to move something that has a lot of water in it, right?

Because water absorbs heat.

Okay, so we got a big change in the tropics.

Where is the air dry

and therefore adding more carbon dioxide would be the primary driver, in terms of surface temperatures?

You already mentioned one.

The Poles.

When the air is cold, is does not pull a lot of water vapor

and therefore adding more carbon dioxide is going to have a major effect in terms of surface temperatures.

Where else is the air dry?
The surface. - I’m really not trying to trick you, this is just basic high school biology.

The desert.

Pardon?

Someone said desert.

Deserts, excellent.

Deserts.

So what do we expect to see with more carbon dioxide?

Increased desertification, right?

Deserts are gonna get bigger.

Makes sense so far?

Okay, gonna add a little bit more to this.

If you go up in elevation and altitude, as you move up in altitude the air becomes dryer, therefore there is gonna be a major shift in terms of temperature.

Seasonally, which season, summer or winter, has the highest humidity?

Connecticut, is it hotter and wetter in July or in December?

Again, I’m not trying to trick you, okay?

All right, it’s July.

The summer is warmer and wetter, so the fact is that temperature is gonna happen more in the winter than it is in the summer, and that’s what we’re seeing okay?

So, here’s the technical message.

If water vapor is high, it’s the dominant warming gas,
and there’s less effect of CO2. If the water vapor is low, adding more CO2 will have a differential higher effect with respect to surface temperatures. Again, I’ve taken an entire semester and given five minutes, but you can hopefully adjust to this, there’s more to it.

So, let’s look at it from the plant biology point of view. Okay, warmer temperatures, well, we know that greater temperature increase with latitude or altitude, based on what I’ve talked about.

Increased desertification, increased drought, rise in sea levels from increased polar and glacial melt. Okay?

So, what’s warm is gonna get warmer, what’s wet is gonna get wetter, and we see these changes going on, right? That’s the indirect effect of rise in carbon dioxide.

Now, let me tell you the other direct effect, or the only direct effect, and that is plants are essential to life.

What do plants need in order to grow? Sunlight, excellent, thank you so much for sitting in the front row. They need all kinds of nutrients; your nitrogen, your phosphorous, your potassium.

What’s the fourth thing they need?
Carbon dioxide, right?
Okay, let’s do this as a thought experiment.
Suppose for the sake of argument that phosphorous, okay,
that the amount of phosphorous had gone up
in every soil around the world by 30%.
By 30% in your lifetime.
Would that have an effect on plant biology?
Yeah, of course.
There are over 400,000 different species of plants.
Would all plants respond the same way to that effect?
No.
And as plants are the foundation or the basis
for life on the planet, for they’re
the bottom of the food chain,
are there gonna be ramifications of that?
Oh, hell yes!
Here’s one of them, I got this from the ExxonMobil
website.
Now that provides strength
but this is lovely fine.
And you can see lovely fine you can (mumbles).
Well look at that, that is so cool.
I’ve only find Rosemary
when you give it more carbon dioxide.
If you’re a forester you understand that the faster
the tree grows the weaker the wood.
But you told me that aside from that wasn’t on the
website.
Oh, hey,
this is Kazoo.
Anybody from the southern US?
Anybody experienced Kazoo firsthand?

Yeah, I know.

We did not in the front doorstep or in the morning.

This is an invasive vine and it also responds to carbon dioxide.

Wow, this is one of the worst weeds in the United, am sorry, I keep saying weeds, the current administration term is alternative crop. So I don’t wanna confuse anybody, okay?

All right, so this also responds to carbon dioxide.

Well what are the consequences of this direct effect of rising CO2? Well, it’s a fundamental resource for plant growth and all plants are gonna be beneficial to human society.

Not all plants respond the same way and rising CO2 alters the qualitative components of plants.

Nobody talks about this because CO2 is plant food and everything is wonderful and good, and everything’s gonna be great. Doesn’t work that way.

So let’s look at the good. Let’s take the good part first, all right?

All of you are familiar with malaria. About 400,000 deaths primarily in Sub-Saharan, Saharan regions. It’s a tremendous and awful storage disease. So, one of the ways in which it is dealt with is through this particular plant. This is Artemisia annua or sweet Annie, okay?
It has been used in Chinese medicine for hundreds of years as a means to combat malaria. It produces this compound artemisinin which is important in terms of killing Plasmodium, the carrier for malaria. So, it is part of what are considered artemisinin combination therapies which is still the primary means to respond to malaria globally. And what they do in this is they take artemisinin compounds, they add different one or two longer acting drugs, usually from the quinine family, they add it to the artemisinin and that’s a means to prevent or help you get over the malaria. And just from a sort of anatomical point of view, the glandular secretion, the trichomes in artemisia when you have a little closer look, that’s where your artemisinin is being produced. Okay.

So obviously, the question I gotta ask is, if CO2 stimulates plant growth, what does it do for artemisinin production? And we worked with a group at Nanjing University and we worked with a group at Nanjing University at the National Academy, the Chinese Academy of Sciences. And they have a FACE of free CO2 enrichment system. We were looking at the artemisinin content as a function of carbon dioxide.
and function of the carbon:nitrogen ratio. So you could use this elemental analysis of carbon and nitrogen as a means to predict how much our artemisinin was being produced by give a plant. And then Chan Jiu who was my colleague there, went to different herbarium around China to look at artemisinin, to collect it and to do this C:M ratio. So we have collections that vary from 1900 to 2005, 2006. And during this time period, carbon dioxide has risen, in sort of a logarithmic fashion, slow at first and then increasing. Is there a connection between this rise in carbon dioxide and the change in the estimated artemisinin concentration produced? And we think there is. Here’s the carbon dioxide levels here in the curve, and here is the estimated artemisinin concentration that we’re seeing for this as a function of decade, as a function of carbon dioxide. In fact, what they’re doing now is that the are forwarding greenhouses where our AC is growing, adding more carbon dioxide as a means to increase artemisinin production now. So this is a good thing. It’s a way of increasing a chemical compound produced by leaves that we know has a positive effect with respect to malarial
concentrations, trying to cure your malarial symptoms. So from the good point of view, Artemisia annua by the way, is a common weed in North America, is a central pharmacological resource to treat malaria in Africa. Recent increases in atmospheric CO2 are associated with the increase of a known anti-malarial drug derived from this plant. What other plant-based drugs are responding? Don’t know? You need find out. Let me give you the bad, okay? This is something I’ve been working on for a number of years and has to do with pollen. How many of you suffer from seasonal pollen allergies? Let me give you the bad, okay? Raise your hand, excellent. Let me give you the bad, okay? Okay, so basically the plants that are associated with seasonal pollen allergies sort of fall into three major taxa; you have trees in the spring, weeds and grasses in the summertime and Ragweed in the fall (mumbles). So we went through and looked at how again, how is carbon dioxide affecting pollen production from ragweed during sampling of catkins. Here are some of the early work that we did, this is great chamber work where we were lowering the carbon dioxide values to pre-industrial levels and all the time back in the 90s and then projecting to 600.
which will almost certainly occur in the century.

And this is the overall plant biomass for ragweed of the branch per plant basis.

Here’s the pollen production going for 280 to 370 double pollen production,

going from 370 to 600 double as you can.

And hey, not only was an increase in growth but only increasing in terms of pollen production,

but also in terms of the antigen Amb a1 based on the ELISA test where going as an increase as carbon dioxide went up as well.

We haven’t been able to replicate this, by the way.

So that’s another challenge for you young researchers that are out there.

But, there’s pretty good indication

that ragweed has this kind of respond.

Yeah, yeah, all the interesting doctors has good interesting stuff,

but it’s a chamber study.

It’s a chamber study,

doesn’t add any relevance in the real world.

What’s wrong with you?

Okay, how do we get from the lab to the real world?

Okay, well, there’s, I showed you

was talking about FACE, FACE free air CO2 enrichment.

This is the Duke University FACE which was funded by the Department of Energy as we refer to it in federal circles, the department that everything,

they had lots and lots of money.

So this is the rain.
This is pushing in carbon dioxide to the low valley pine forest showed you the effect of CO2 on low valley earlier.

This is an afterward, it turns out that plants do respond differently, you know the plant that responded the most with this change?

Within the forest understudy?

Of course you don’t.

I’m sorry (mumbles)

There’s a problem here.

The problem for me was this cost $5 million a year. My entire discretionary budget at the time was $2,000. I could hire it for maybe five minutes, but that’s not really gonna work. So, I kind of like, how do I take it from the lab, to the real world, how do I do that?

Hang on a second.

Let’s go back to the Keeling curve. Why did they measure this in Hawaii?

I mean, I like Hawaii. It’s got great factories.

Why would you measure carbon dioxide background in Hawaii?

High elevation and well background carbon dioxide?

Exactly.

Exactly.

So you’re measuring the background carbon dioxide,
you’re not measuring the carbon dioxide in the room here,
which I chose over the camp 11.
Or if I go out in the street and measure carbon dioxide.
So that gave me an idea.
Yeah, so most geological, geographically isolated spot
on Americans have high emissions,
but maybe we could use an urban-rural transect as a means
to simulate what future environment would be like.
If I move the temperature and a carbon dioxide transect
along this line from an organic farm in Western Maryland
to downtown Baltimore, we dug the plots and moved
the soil,
we made the soil uniform at the same seabed
and so the seed was the same.
We monitor all this fairly carefully.
And I’m sorry, as an academic,
I gotta show you at least one slide
that nobody in the back row can read.
So this is my contribution to that.
And so try to go through it.
This is daytime CO2, early 2000s.
It does go up with going from rural to sub-urban.	Night-time temperatures go up,
season light goes up the number of forestry days.
Now there are some day time temperature,
now there’s some concerns here.
One of them is ozone.
Well, it turns out that when you had an ozone,
day in downtown Baltimore, within four hours,
you got the same ozone occurring at the rural site.

So we didn’t think that was too much of an issue.

Yeah, we did get more hydrogen deposited and rainfall for the urban side relative to the rural side.

But the soil that we took out to each location already had a great deal of nitrogen in it, it was firm, so from the same source.

So we don’t think that was too much of a problem.

Since there we are, two meters by two meters, digging down into the soil, if you look closely, you’ll see Jenny Hopper (mumbles).

Okay, so we did that.

And we packed the soil, the seed bank down, we took out our railroad samplers here to monitor falling around each of the sites.

And hey, cool.

We got in the farm site, the rural site years here’s when the ragweed first showed up, the pollen first showed up around day of year to sometime in September, peaked and then went down.

Okay, now, these two lines here, these two arrows, are the start of the maximum pollen based on the farm side, sort of out of control.

And you can see it if I go to the semi rural, the sub-urban areas starting earlier and maximizing the warmer when we get to the cities.

Holy cow!

The individual ragweed plant in the city
with more CO2 with more temperature and a longer growing seasons producing on average 10 times more pollen than the one out in the country. Wow, okay. That was a cheap way of getting a featured climate. Yeah, okay, that’s interesting. Yeah, it’s a global climate change. How do we scale up from this? Well, I use a very sophisticated instrument on my desk called telephone. And I called up different allergists and medical doctors and said, "Hi, you don’t know me, but I’m a plant physiologist from USK Oh, no, don’t hang up, don’t hang up. "Hi, am a plant physio you don’t know me, "but would you be interested? “Oh, you would, okay, great, hang on.” So what we did is we got allergists and other pollen counters across the central part of the United States to look and see whether there had been a change in temperature that could be associated with the change of pollen season for ragweed. Now, we didn’t look at ragweed numbers per se in terms of the amount of pollen just whether or not the season have been affected. And so what we found was beginning in the 1990s. And if you start down here remember remember that humidity CO2 paradigm?
Right here, it’s warm and wet.

We’re not expecting a big change in recent decades in terms of temperature, but it shouldn’t expand as you move northward.

And that’s kind of what we saw. That now going up into the northern part of the US that from 95 to 2013 there’s hardly has been a significant increase in the ragweed pollen season.

Okay, well, we’ve gone from the lab, we’ve gone to the city, we’ve gone to the country, let’s do the world.

Now when I called up they said, “Oh, I have a paper and PNAS, please listen to me.” And they would listen. "So yeah soil paper that’s really interesting. We wanna help you.

Okay, so started getting data this is from Turku, Finland. One of the longest pollen seasons that we had.

This is total seasonal pollen, in terms of grains per cubic meter over time.

Reykjavik, Iceland, grains per cubic meter over time. Kansas City, Missouri, we’ve since found out this probably not correct because it’s a long story, but they got a new pollen counter, it was much better in counting pollen (mumbles).

Geneva Switzerland.

Okay, you’re seeing, if you’re seeing, I think it’s fair to say a trend here, a global trend.

Right?
So basically, we went out on a lab and looked at the change in pollen load, the amount of pollen over the end of the season as a function of different temperatures. And where there was some good significant correlations here in terms of, based on locations around the world. But all of these locations are in the northern hemisphere. So our next goal is to go to the southern hemisphere. And we’re working on that now, so stay tuned.

Alright, so that rising CO2 temperatures can influence pollen season falling amounts. Pollen allergenicity, we’re still not sure, we have one laboratory data. Maybe, maybe not, we need to do more work on that, right?

Okay. Let’s go to the OMG part. Right, this is... What’s the role of carbon dioxide if the trees are growing bigger and there’s more water available, does that affect fire frequencies? I don’t know.

Is it possible it’s affecting the qualitative component of the woods such as burning the higher climate change or more CO2? Is it affecting the air pollution pollen? I don’t know, nobody’s said a word. We talked about Kazoo earlier, well Kazoo when you give it
0:27:23.073 –> 0:27:25.03 more carbon dioxide, generates
0:27:25.03 –> 0:27:27.28 more volatile organic compounds.
0:27:27.28 –> 0:27:30.033 Has that shifted in the last 20 years of more CO2?
0:27:31.09 –> 0:27:31.923 I don’t know.
0:27:33.26 –> 0:27:35.22 Well, what about contact dermatitis
0:27:35.22 –> 0:27:36.49 from something like poison ivy?
0:27:36.49 –> 0:27:38.61 We actually know this one, I mentioned that this was
0:27:38.61 –> 0:27:40.46 the one that was growing more
0:27:40.46 –> 0:27:42.89 in the FACE system in the deep forest.
0:27:42.89 –> 0:27:45.71 It actually produces a more virulent form of urishiol.
0:27:45.71 –> 0:27:47.891 You get contact dermatitis faster
0:27:47.891 –> 0:27:50.9 when you come in contact with it.
0:27:50.9 –> 0:27:52.023 What about narcotics?
0:27:53.03 –> 0:27:54.4 We spend billions of dollars a year
0:27:54.4 –> 0:27:56.073 trying to eradicate narcotics.
0:27:57.43 –> 0:27:59.53 How is CO2, how is climate affecting
0:27:59.53 –> 0:28:02.034 where these narcotics are growing?
0:28:02.034 –> 0:28:03.117 I don’t know.
0:28:04.39 –> 0:28:06.52 What about food allergies?
0:28:06.52 –> 0:28:08.89 If I’m changing the quality of the composition of the food
0:28:08.89 –> 0:28:11.506 is it affecting the number of food allergies?
0:28:11.506 –> 0:28:13.05 I don’t know.
0:28:14.49 –> 0:28:16.25 Food safety, hey,
0:28:16.25 –> 0:28:18.7 everybody gets sick from eating food occasionally.
0:28:18.7 –> 0:28:19.85 Turns out warmer temperatures
0:28:19.85 –> 0:28:22.23 can promote pathogen infestation.
0:28:22.23 –> 0:28:24.29 Oh no, who knew?
0:28:24.29 –> 0:28:26.48 Is climate change or rise in carbon dioxide
0:28:26.48 –> 0:28:28.263 affecting food safety?
0:28:29.33 –> 0:28:30.47 I don’t know.
Funding for all of these things from the federal government is, yeah. Nobody’s doing anything worse. Here’s some work we did do. This is kind of thistle highly invasive species. This is being sprayed with glyphosate, the recommended rates under ambient CO2 that’s being sprayed with glyphosate under 650 parts per million CO2. And added absolutely no control. The reason why, is that when you give them more carbon dioxide, there was a difference between how much would accumulate on the top and how much accumulated in the roots. It did not, one of the things that glyphosate does is it travels, it’s systemic, it goes everywhere in the plant. But if I have more roots, it was diluted out and roots can generate new shoots, et cetera. So what’s the effect of carbon dioxide and climate change on pesticide usage? But if I have more roots, it was diluted out and roots can generate new shoots, et cetera. We know about this much. If there is a green revolution, if there is a green new deal these are the things that we need to focus on. Let’s work on one of these issues. There’s not enough time to go into all of them. Let’s look at nutrition. And let’s look at rice. Rice is consumed on a daily basis by

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About two billion people.

About 600 million people get more than 50% of their daily food intake from rice.

Rice, wheat, corn, they’re what we call the big three that account half of the calories that you consume and I would be willing to bet all my life savings that you’re consuming at least one of them for this lunch.

There’s pretty good evidence that projected increases in CO2 reduce proteins.

Some of the first work that I did back at the International Rice Research Institute, doing open top chamber work with different temperatures.

For the 94 wet season, our percent protein was about 10% of ambient CO2, we had a CO2 it dropped 9.3%, the dry season similar response in terms of temperature per se, reduced protein levels, but it did not interact with carbon dioxide.

The change in protein is ongoing.

We looked at future changes. This is recent changes from 300 to 400 parts per million for about eight different rice lines.

And here I think eight of the nine showed a decline or significant decline in protein concentration for the rice.

And we had to stop this because our funding got hold when new administration came in.

It’s ubiquitous, here’s some work by Taub.
Here was in Texas and this is looking at annual crop staples; barley, rice, wheat, soybean, potato.

This is the number of studies, average and standard deviation. This is the percent change in protein concentration under elevated CO2 which range from about 600 to 700.

All of them declined with the exception of soybean. Soybean is a legume, that’s to say it fixes its own nitrogen. So when you add more CO2, it’s not affected.

So soybean, peanut, other leguminous plants do not show that change in terms of proteins with more carbon dioxide.

This is some work by a colleague Irakli Loladze, he went through and looked at the Sweden country of all the different elements in the context of rising CO2, the average of about 690.

And what we see is that this very rapid rise in carbon dioxide is causing plants to be carbon rich, but nutrient poor across the board. And we think there are ramifications of that.

So it’s not just crops. We’re looking at at personal work that is done by me, or that is done by Augustine and all, came out recently looking at pasture grass that have been grown under elevated CO2.

And what effect this had in terms of weight being put on by the cattle.
And this is a seven year average, we’re looking at ambient CO2, ambient temperature; ambient CO2, elevated temperature and then the two bars on the right are elevated carbon dioxide to different temperatures. 20% nitrogen which is a proxy for percent protein declined significantly with more carbon dioxide. The animals put on weight, took them longer to put on the same amount of weight, they were slower growing. So there’s pretty good evidence across the board that plants are responding by reducing protein levels. That’s going to have ramifications in terms of human nutrition, direct consumption, but also in terms of livestock. Hey, but it’s just people food, right? Well, no, not necessarily. We decided to look at bees. And turns out that, you know, bees also have nutritional requirements that are important in the context of agriculture. So they get their carbs from nectar. Understandable, so then they do this, they’re really good at it. They do the little waggle dance. You know, the little waggle dance the bee says to the other bee, “Hey, you know if you go right behind this building, there’s a sunflower there, 20 feet to the left of the dumpster and you’ll find all the carbs you want.”
They’re really good at that.

They’re not so good in terms of pollen yet pollen is their main source of protein,

they get 10 essential amino acids from the pollen that they consume.

So again, we wanted to see okay well carbon dioxide is this in fact affecting bee nutrition? And let’s do it from a point of view of the recent changes that occur.

That’s a tough one to get to. How did we, we chose Goldenrod because Goldenrod is one of the last sources of pollen that bees see in the fall before they overwinter.

I won’t go through all the machinations we did to come up with that, but it is.

And so it’s important for bees before they overwinter to have a good source of protein, and one of those good source is Goldenrod so we considered it to be a key for the species.

So what I’m trying to do is sort of two lines of evidence here and I wanna give you the historical evidence first.

And they got this through, this Smithsonian Natural History Museum. Now, I don’t know if you’ve ever been to DC but it’s a great place to go, you got your dinosaurs, you got your elephants, you got your little diamonds, it’s a great place to go, right?
Okay, but here’s the thing, way in the back in the basement,
right next to the Ark of the Covenant,
you’ll find all these, okay (mumbles)
You’ll find all these plants samples, right?
They go back to pre industrial times in the 1850s, 1860s.
And those samples included Goldenrod.
So we’re able to actually take the pollen,
the stigmas, the reproductive parts,
and to look at the carbon, hydrogen, nitrogen ratios.
Nitrogen as a proxy again for protein.
Now, I wanna give you a second line here.
This is the experimental evidence.
This is some work that was done by my colleague,
a scientist down in the Temple, Texas.
He’s since retired but this is a really cool study,
waiting kind of for guy.
Kind of circle wagons that you see here.
What Wayne did is, he added carbon dioxide
at one end of the wagon.
And because of photo-sensors and because it’s Texas
where the sun’s shining all the time,
by the time you got to the bottom wagon,
all that carbon dioxide have been taken out.
So they were looking at carbon dioxide levels
pre-industrial, right 283 hundred.
And we were very fortunate to have just enough gold-
and growing along that trans sector
that we could actually look at the numbers.
So here are the data.
This is historical data from the Smithsonian. This is the estimated protein based on using nitrogen as a proxy. And going from the pre-industrial time to the current time, which is the beginning of the 21st century.

We see about a 30% drop in the nitrogen protein content and an increase, corresponding increase in carbon and the nitrogen of that pollen. And for the experimental evidence, numbers are slightly different. There’s a lot of the sampling so the larger the bigger, but basically the same sort of response; that as you increase the carbon dioxide, you’re decreasing the amount of protein in the pollen. That has effects in terms of the health. And these are already under environmental stressors. How’s it affecting that?

We don’t know. We’re not able to get funding to continue this work. But we think it’s a toe in the water stage where we think it’s really interesting we want to do more if we can.

Let’s go back to people food for a moment. And let’s look a little more deeper into rice. This is work that was done two different FACE of free air C02 reference systems, one in Scuba Japan, which is shown here, another one in near Nanjing, China.
And again, you’re going your rice, you’re ejecting carbon dioxide into a field situation. They did this, we did this under different cultivars, rice cultivars, eight different cultivars in Japan, most of the Japonica lines, some of the (mumbles) lines and then also in China which had a wider range in terms of indica, hybrids and so forth. So the 18 different lines altogether was the percent protein. Again, this is, the differences now, were about 550 parts per million, which is the elevated 400, which is the ambient for all the lines. Percent change relative to ambient CO2, again trying to decline in protein for the rice. You look at iron and zinc, a little more scattered, but again many of the lines, showing a significant and rice overall showing a significant decrease. Now, we wanted to delve a little bit deeper and look at it in terms of the vitamin content. And we didn’t have this for all the different samples but for the Chinese ones. So B1 vitamin, B1, B2, B5 and B9. And I haven’t had time to go through all the stats on, there’s a whole, there were significant effects in terms of all these declining as you increase the carbon dioxide, okay? And then we got this out of the blue, the response,
it went up for alpha tocopherol, okay?
Vitamin E went up with more CO2.
So I was scratching my various body parts
trying to figure out what the hell is this about?
What’s going on, okay?
Well, we have a working hypothesis
for a possibility is definitely needed, all right?
And here it is.
If you look at all the different compounds,
and if the compound has a lot of nitrogen in it,
seems to be selected against, whereas tocopherol
which has no nitrogen actually showed a slight increase
as carbon dioxide went up.
The more nitrogen the compound had,
and this is just a ratio of the molecular weight,
So vitamin B9 has, 20% of the provided
vitamin B9 is nitrogen.
So it follows along pretty good curve.
So perking back to artemisinin.
Artemisinin have no nitrogen in it,
it went up with more carbon dioxide.
So now we have eight points or nine points.
We’re still trying to figure out.
Is this real or not?
We have some recent information
for coffee, more coffee produces caffeine.
Caffeine is a bicyclic alkaloid
with a lot of nitrogen, right?
So we have some initial information suggesting
that caffeine is going down.
I know that’s disappointing, right?
0:40:49.1 → 0:40:50.83 Trust me when I tell you I was very disappointed,
0:40:50.83 → 0:40:53.29 I couldn’t have gone through grad school without it.
0:40:53.29 → 0:40:55.88 But it’s something to keep in mind.
0:40:55.88 → 0:40:58.28 And but having said that, there was also variation
0:40:58.28 → 0:41:01.373 among the different arabica lines that we looked at.
0:41:02.79 → 0:41:07.52 All right, we tried to take all this information and say,
0:41:07.52 → 0:41:09.97 how does it affect different countries?
0:41:09.97 → 0:41:13.95 And we looked at it from the point of view of,
0:41:13.95 → 0:41:15.84 depending on the economics of the country,
0:41:15.84 → 0:41:19.7 if I'm a very poor country, I tend to consume a lot of
rice.
0:41:19.7 → 0:41:23.97 For example, as China has become, as the economic
status
0:41:23.97 → 0:41:26.04 of the Chinese has increased,
0:41:26.04 → 0:41:27.647 then the less rice is being consumed
0:41:27.647 → 0:41:30.06 and a more diverse diet is happening.
0:41:30.06 → 0:41:32.42 So there are usually out of the Chinese I think,
0:41:32.42 → 0:41:33.427 are the green lines here.
0:41:33.427 → 0:41:36.03 But we looked at a number of different countries.
0:41:36.03 → 0:41:39.703 And basically, the poorer the country,
0:41:40.82 → 0:41:42.87 the greater the deficit for the different
0:41:43.95 → 0:41:47.92 actually trying not to confuse myself anymore.
0:41:47.92 → 0:41:50.24 But basically, the poorer the country,
0:41:50.24 → 0:41:54.51 the greater the effect in terms of CO2 impacting nutri-
tional
0:41:54.51 → 0:41:56.51 value of the rice that’s being consumed.
0:41:57.7 → 0:41:59.29 And then we’re trying to look at
0:41:59.29 → 0:42:01.81 the 10 poorest countries in the world.
0:42:01.81 → 0:42:03.46 They’re mostly agrarian.
0:42:03.46 → 0:42:06.08 This was the food production in metric tons,
0:42:06.08 → 0:42:07.373 million metric tons.
0:42:08.32 → 0:42:11.09 This is the population here.
And then you can see food production relative to population is declining. This is the kilograms per person per year. And we’re trying to also look at the elevated CO2 effect on protein. This is some work I’m doing with the broccoli, where he spent a sort of an estimate on the effect in terms of protein for these other staples, some of the staples are, that are dominant in these countries to solve the maize, potatoes, rice, sorghum or sweet potatoes, but again… First, sorghum used to try much but there’s a lot of decline in terms of protein concentration for these products.

What else could be changing what’s happening to the item, of course countries we don’t really know for sure. Alright, so I didn’t really get a chance to go into all of the things in part because there’s just not a lot of information out there to go into. But just looking at one, the nutritional aspect, you get a sense like Oh, of just how fundamental an aspect this is and how important it can be. So plants interact by multiple means in the health of our quality, the medicine and nutrition, and maybe more than just people plants with this life. How is it going to affect in terms of having a global impact? A lot of questions to be addressed. But here’s the thing to keep in mind. If you look at it from the point...
0:43:36.6 –> 0:43:38.86 of view of animals and plants,
0:43:38.86 –> 0:43:41.24 and you weigh all the animals weigh all the plants
0:43:41.24 –> 0:43:42.673 in terms of their biomass.
0:43:43.83 –> 0:43:46.563 All animals are shown here.
0:43:47.7 –> 0:43:49.293 They weigh about two gigatons.
0:43:50.605 –> 0:43:53.033 Plants constitute about two gigatons of carbon.
0:43:56.42 –> 0:43:58.36 All the rest is plants and
0:44:01.73 they constitute 450 gigatons of carbon.
0:44:02.21 –> 0:44:05.7 If I affect plants, I’m going to affect
0:44:05.7 –> 0:44:07.89 every living thing on earth.
0:44:07.89 –> 0:44:12.22 And yet the CO2 as plant food mean dominates our
0:44:12.22 –> 0:44:13.867 It’s much more than that.
0:44:16 –> 0:44:17.3 What are the consequences?
0:44:21.6 –> 0:44:22.85 Where do we go from here?
0:44:24.02 –> 0:44:27.71 Well, we acknowledge that there’s interaction,
0:44:27.71 –> 0:44:30.94 that carbon dioxide also needs to be looked at.
0:44:30.94 –> 0:44:33.01 We acknowledge that the potential research
0:44:33.01 –> 0:44:36.05 in the context of public health is enormous.
0:44:36.05 –> 0:44:38.7 There’s so much more that we can be doing with this.
0:44:38.7 –> 0:44:41.773 What can we do to work together?
0:44:45.285 –> 0:44:47.7 What can we do, what can we do as a means
0:44:47.7 –> 0:44:51.744 to find new opportunities,
0:44:51.744 –> 0:44:56.36 new ways that we can come together to try
0:44:56.36 –> 0:45:00.37 and find new research to do on this area
0:45:00.37 –> 0:45:03.117 that we haven’t been able to find yet.
0:45:03.117 –> 0:45:08.117 And I’m hoping that at some point, this will come
to pass.
0:45:08.527 –> 0:45:10.068 So thank you all very much for your time.
0:45:10.068 –> 0:45:13.068 (students clapping)
0:45:15.081 –> 0:45:17.215 - [Kai] So now is the question time and
if you have a question, just raise your hand ask it.

I know it’s a lot of information people.

Yes.

I just wondered if any...

You know, you said that tocopherol might not go down

because it’s not, in a way, it doesn’t contain nitrogen.

So how’s that experiment you’ve done when on (mumbles)

available - [Lewis] Yeah this is one of

the things that occurred to us initially was that

what we’re seeing is because of stimulation of growth,

and there’s a position (mumbles) of nitrogen.

So to counter that we made sure that

we had the chamber experiment where we could really vary

the amount of nitrogen but also ensure

that we’re getting super amounts of nitrogen

something like and is one of (mumbles).

[Student] Great work - [Lewis] Yes.

I’m sorry.

No, that’s great work.

Have people looked at

sea grasses and aquatic plants?

No, not to my knowledge.

Not to my knowledge.

Yes.

So, as you mentioned in your view,

the cost is highly variable costs probably 10 hours ago.

They are paid by the common practices,

so, I guess that by, to what extent or stage
0:46:37.13 –> 0:46:41.46 is impact of climate change will have observance of
0:46:42.657 –> 0:46:45.28 human health outcome and also
0:46:47.37 –> 0:46:51.573 using all this technology of reading,
0:46:52.57 –> 0:46:56.61 nutritious varieties and also different farming practices
0:46:56.61 –> 0:46:58.37 and also intensification to
0:47:01.06 –> 0:47:03.34 increase productivity as a
0:47:06.253 –> 0:47:10.384 to what, kind of, what can you say all these tests
0:47:10.384 –> 0:47:13.25 can help us to (murmurs) and damage to the plants?
0:47:13.25 –> 0:47:15.22 - [Lewis] There’s a lot in there.
0:47:15.22 –> 0:47:17.287 So let me try and actually to address
0:47:17.287 –> 0:47:20 that particular number entire somehow.
0:47:20 –> 0:47:22.7 But let me try and address it quickly.
0:47:22.7 –> 0:47:24.905 One of the things that we’re currently doing and nutrition
0:47:24.905 –> 0:47:26.16 is currently doing justification,
0:47:26.16 –> 0:47:28.72 we’re using what are called monocultures.
0:47:28.72 –> 0:47:32.05 The genetics of the crop that you’re growing all the same.
0:47:32.05 –> 0:47:35.36 So as you get rid of small landowners,
0:47:35.36 –> 0:47:38.18 which have more diverse genetics, and you go
0:47:38.18 –> 0:47:39.743 to bigger and bigger fields,
0:47:40.76 –> 0:47:42.143 there are different reasons for it
0:47:42.143 –> 0:47:45.5 that it becomes more and more uniform, has to be.
0:47:45.5 –> 0:47:48.02 The problem with becoming more uniform, you don’t have
0:47:48.02 –> 0:47:53.02 a diversity necessary in order to find the lines
0:47:53.57 –> 0:47:56.87 that are you could say different to their effects
0:47:56.87 –> 0:47:58.67 and CO2 and with respect to protein.
0:48:00.398 –> 0:48:02.49 That’s part of our job or it was part of our job
0:48:02.49 –> 0:48:04.99 when I was with USDA is to begin to look at these
0:48:04.99 –> 0:48:08.483 different lines and to look at how they might respond.
0:48:09.71 –> 0:48:12.25 Part of it is management and began there are different
aspects of that as well, because of rising water product prices and water consumption.

Flooded rice is not as grown as much as it used to be. And it has a whole nother suite of consequences that I unfortunately don’t have time to, we could talk more about it after class if you wanna know more.

What we are currently doing in terms of breeding is we’re seeing two dissimilar breeding attempts.

We have farmers and breeders who are breeding for yield and breeding for taste and breeding for insect resistance. And as CO2 is going up in nature, we think that in itself is having a selection effect.

So for example, we see wild rice, weeded rice, is showing a much stronger response to the change, recent changes in CO2 and cultivated absence.

And they’re actually putting more of that additional carbon dioxide into seedling for the weeded rice.

So we think that there’s an opportunity here as well. And that is to look at the weeded rice as a means to begin to adapt to, for the cultivated rice to adapt, to look at the both technology and genetics of the weeded rice as a means to begin to bring or adapt cultivated rice, so that it can not only respond to warm climate, but actually might benefit by it.

Okay, anybody have a cell phone? Would you google something for me?

This isn’t about… is that okay?

Okay.
Would you, and this is not about rice, but just for fun, would you google carbon dioxide and marijuana and tell me what the first sentence that you get. What does it say? How do you use CO2 increase yields in your marijuana. Can you say that louder? How do you do CO2 to increase yields in your marijuana crop? So I’m guessing here that if they can do that and literally they have indoor chambers and they’re doing it you know that way. But remember the CO2 has already gone up by 30%. Are we missing out on an opportunity by not taking the increase that’s already occurred and begin to find the best suited genotypes that can take that increase and divert them into seeds. I can go online, I can do this in more depth, I can find out from the marijuana industry, when to give the CO2, how much to give the CO2, what the temperature is to give the CO2, what the hormone THC I can get from the CO2 will be. Why can’t we do that for food? I would argue there’s an opportunity there. Anyway So... Yes. How’s it that when kind of follow the
mass cyber, there isn’t any much of a research into trying to (mumbles) the decrease in vitamins and minerals in the plants and to actual public health in the past?

We haven’t done that yet but, that’s one of the things we’d like to work on. We put in a convergence RFP for NSF to do that.

And they turned us down.

So we, I know, we’re still on track.

I think it’s important.

Yeah, on that note, I mean, I couldn’t help but wonder in your, during your presentation, if the increase or if the alarming increase in malnourished, obese folks might have, you know, if I’m sorry, can’t talk to the, I just gave up coffee.

I couldn’t help but wonder if that could potentially be some contributing factor to this concurrent prevalence of obesity alongside malnutrition.

We don’t know, we think it could be, certainly logically interpreted there’s...
0:52:52 –> 0:52:53.38 the numbers just to show it.
0:52:53.38 –> 0:52:54.23 - [Student] Sure.
0:52:55.15 –> 0:52:57.535 - [Lewis] So unfortunately, that at the moment,
0:52:57.535 –> 0:53:02.493 it’s the Chinese folks, we just have to ignore it.
0:53:02.493 –> 0:53:05.09 - [Student] I also had another thought and maybe it’s
0:53:05.09 –> 0:53:06.42 for everyone in the room,
0:53:06.42 –> 0:53:08.76 just from a public health stand-point,
0:53:08.76 –> 0:53:09.8 you know, are there...
0:53:09.8 –> 0:53:13.83 do we know of any large ongoing sources of data
0:53:13.83 –> 0:53:18.83 that actually, that ask about allergy, food allergy
0:53:19.39 –> 0:53:21 or environmental allergy?
0:53:21 –> 0:53:23.76 But this isn’t my area of research,
0:53:23.76 –> 0:53:25.327 but does anyone know of any?
0:53:27 –> 0:53:30.06 - I don’t imagine that there are databases
0:53:30.06 –> 0:53:33.837 for food allergies that are available.
0:53:33.837 –> 0:53:35.537 I don’t know how far back they go.
0:53:37.885 –> 0:53:40.92 And it would be difficult thing given the other issue
0:53:40.92 –> 0:53:45.24 in epidemiology is early exposure, and other aspects
0:53:45.24 –> 0:53:47.42 that make it difficult to try and assess with
0:53:47.42 –> 0:53:49.863 a separate role of climate of carbon dioxide.
0:53:51.17 –> 0:53:52.22 But it’s a good idea.
0:53:53.29 –> 0:53:56.603 We did, I didn’t mention this, but we did a study on
peanut,
0:53:58.3 –> 0:54:00.57 we have two different varieties of peanut
0:54:00.57 –> 0:54:03.331 which we grew at different carbon dioxide concentra-
tions,
0:54:03.331 –> 0:54:07.88 and over a two year period, and one of the varieties
0:54:07.88 –> 0:54:11.105 for both years showed an increase in Arachis stage
one.
0:54:11.105 –> 0:54:14.277 Arachis is peanut genus that’s also the name
0:54:14.277 –> 0:54:17.45 of the primary allergen that peanuts produce.
0:54:17.45 –> 0:54:18.427 It’s about a 10% increase in the allergen,
but the other one didn’t do anything.
So it needs more work.
We need to find out why is this line responding
the other line not responding.
What’s going on?
We just don’t know.
Yes.
I have kind an answer to your question.
I mean, those collect technology
so they have some (mumbles) from 2007, 2010.
Probably just some recorded geology.
And it looks like they have problem (mumbling)
the categories so...
Oh, awesome, thank you.
Okay, yes, last question.
That is (mumbling) though is that
the total climate change mitigation challenges
that mattered, is there any one focusing on
the technology challenges (mumbles)?
There are a number of things, for means better
at the management level, but also at the genetics level
and at the consumer level and we think,
within the food system are ways to reduce
greenhouse gas emissions.
So for example, one of the things that USDA was working on
before I left was
was called
water deficit irrigation with rice.
Typically, rice is flooded because
it’s a way of keeping weeds down.
And, but flooding rice also produces a lot of methane. And so if you change the management, you can reduce the amount of methane that's being produced. But farmers are worried and of course, they do that, that's going to reduce the bottom line of production. So USDA was doing studies trying to look at alternative drawing and say that they did management plan as a means to see if it would reduce methane. Because you can't wag your finger at a farmer and say you're producing too much methane. But you can go up to them and say, "Hey, you know, I've got this great idea that's gonna increase your yields, but also reduce your cost for water, " but also reduce your cost for water, "oh by the way, it’s gonna reduce the methane, "oh by the way, it’s gonna reduce the methane, “but you don’t care.” And just go, go with that. There’s lots of opportunities. What if you were a pure consumer, and you’re at the market, and you’re looking at buying a package of beef, and you're looking at buying a package of beef, what if the information was there, it says how much of my greenhouse gas feature, for buying this kind of beef for us? Yeah, you know, I could compare it to different brands to see, okay, well, I’ve got three different brands of beef here, but hey, this one's producing much less greenhouse gas, maybe I should buy this brand. So yeah, there’s lots of really cool, interesting, fun things to look at.
I mean, it’s just, it’s a question of having the resources to do it.

Okay, thank you for this kind, I think it was an excellent lecture.

Although we have a few, many but all of us have an interest.