20/20 Exclusive:

Monomania:

A study on the future and sustainability of monoculture farming practices

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Heather Wheat: Hello and welcome to tonight's 20/20 exclusive report, *Monomania*. Tonight's episode features scientists and activists from around the globe discussing traditional and modern agricultural practices, and common themes of controversy surrounding such practice. As the world population continues to grow, high demands for food have encouraged agriculturalists to seek practices that produce large quantities of food with reliable harvests. The demand for uniformity has led many farmers to turn to monoculture: cultivation dominated by a single crop. Our reporters spoke with an array of experts in the field in an attempt to discuss sustainability of monoculture practices, their alternatives, and how modern farming will change in the future.

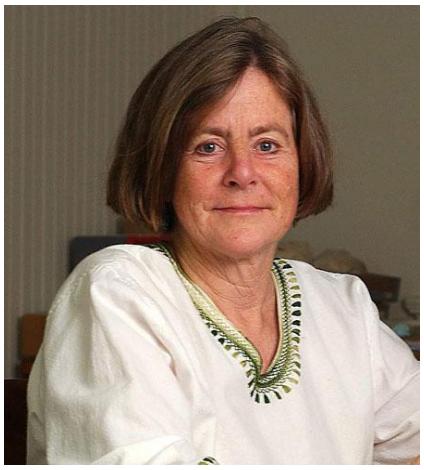
Here is a brief introduction of our interviewees featured throughout tonight's program.

William Hewitt:

Mr. Hewitt is a long-time environmentalist and writer. He was the Director of Public Affairs for the NYC regional office of the New York State Department of Environmental Conservation for 11 years and has been involved in multiple Presidential and Mayoral campaigns. He currently serves as an Adjunct Assistant Professor at New York University and has written a book, *A Newer World – Politics, Money, Technology, and What's Really Being Done to Solve the Climate Crisis*, about current environmental issues.

Jonathon Harrington:

Mr. Harrington is a chartered biologist working in the field on advanced crop technologies. He is currently the Technical Director at Optima Excel Ltd. in Wales advising businesses on advanced agricultural techniques and on food supply. He is a consultant for Cropgen, an organization that promotes crop biotechnology. He also has a small farm in the Black Mountains of Wales.



Catherine Badgley:

Dr. Badgley is currently a research paleontologist at the University of Michigan, and a lecturer for the University's Residential College. She completed her undergraduate studies at Harvard University where she received a Bachelor of Science in geology. She then completed her master's degree in forestry and environmental studies at Yale before coming to the University of Michigan as a fellow in 1982. Since her time as a fellow, Badgley has held both a lecturer and research position, traveling throughout the United States as well as Pakistan, Kenya, and China to complete her paleontological research. Her interest in agriculture and biodiversity has also led her around the globe in search of alternative farming methods and improvements to the current food industry.

Lisa Young:

Dr. Young is a lecturer of anthropology at the University of Michigan. She completed her Bachelor of Arts degree in anthropology at the University of Michigan before continuing on to obtain a master's degree and Ph.D. in anthropology from the University of Arizona. Her research focuses on the origins of small farming in Southwest America, particularly in arid drylands, as well as aspects of household and community organization.

C.S. Prakash:

Dr. Prakash is a leading figure in biotechnology and agriculture. Dr. Prakash holds a bachelor's degree in Agriculture, a masters degree in Genetics and Agriculture, and a PhD in Forestry. He is a professor of Plant Molecular Genetics at Tuskegee University, where he also established a training program in plant biotechnology. Dr. Prakash has served on many panels, including the USDA's Biotechnology Advisory Committee. He also works to reach out to the general public on issues of biotechnology, and has appeared on numerous programs such as BBC TV, Time, Wall Street Journal, 20/20, and NPR, and has given talks at Harvard, Stanford, UC Berkeley, Purdue, Cornell, the United Nations, U.S. Congress, and dozens of other prestigious organizations. He has received *Progressive Farmer*'s "Man of the Year" award, and was recognized by *Nature* as one of "biotech's most remarkable and influential personalities from the past 10 years."

Simone Lovera:

Ms. Lovera is the director of the Global Forest Coalition, an international coalition of NGOs and Indigenous Peoples' Organizations that focuses on forest conservation policies and human rights of indigenous people. She has a degree in Dutch and international environmental law. She began her career as a coordinator of the legal program of the Netherlands Committee for International Union for Conservation of Nature. She is also co-coordinator of the Friends of the Earth International Forest Program and a guest researcher at the Amsterdam Institute for Social Science Research of the University of Amsterdam.

HW: We start our program tonight with an interview with Lisa Young, an anthropology lecturer at the University of Michigan who has studied the origins and benefits of small farms, discussing the cultural impact some of these traditions have on modern communities. From there, we kick off our exploration of whether or not monoculture practices are helping or hurting our ability to

produce and access food around the world, and whether these practices are sustainable for the future of our soil, plants, human rights, and animal safety. Have we pushed our technology so far that we cannot go back to traditional practices? Can biotechnology help us counter the issues we are facing with monocultures?

Please join us tonight, alongside experts in the field, in understanding the impact of local farming applications and large, industrial monocultures that shed light on the future of growth and sustainability.

Raoul Martin: Welcome Lisa! Thanks for agreeing to speak with us this evening. You've studied early agriculture in the Southwestern United States, focusing on the Native American Hopi tribe. When most people think of monocultures today, they think of corn. Would you please tell us a bit about the beginning of corn farming in the United States? Did early farmers have combinations that helped them grow their crop better? What were their strategies?

Lisa Young: Corn was first domesticated further South, in Mesoamerica, about 4000 BC. It was then brought into the Southwestern United States as a domesticated crop. It was originally domesticated in a tropical environment, and then it had to be adapted for the dry land farming that happens in the Southwest. Our earliest dates on corn in the Southwest are about 2000 BC, and we don't see it becoming an important part of peoples diet until somewhere between 600 and 800 AD. It was snack food, literally popcorn, for a long time, and yet we think of corn as requiring all this time and labor to grow, but somehow people were growing it while they're still moving around a lot on the landscape. They're also growing some beans and squash. Our first evidence of squash down in Mesoamerica was about 8000 BC. It looks like they were growing it initially for the seeds, maybe roasting the seeds for snacks.

Agriculture really doesn't take off until you get both beans and corn together. Complementary amino acids in both the corn and the beans make it a more complete protein, and then the squash has those nice seeds that have a lot of fat in them, and it's really the combination of those together that we see. That's when we also see people getting more cavities, and there's a big population explosion at the same time, so we're also seeing a lot more disease, but the great thing about corn is you can feed a lot of people on a small plot of land it's very productive. However, it's kind of crappy calories. In the Southwest, what we see is people doing small-scale gardening initially, eventually settling down becoming more and more reliant on agriculture, but it's always a diversity of crops that they're relying on. The corn needs water at critical points. If it doesn't get enough moisture right at that critical point, which is in the middle of the summer in the Southwest, it won't produce any ears. So it's much riskier than beans. Here in the Midwest, the traditional way of farming is actually the Three Sisters farming, where you've got corn and then the beans wrapping around it, and the squash on the bottom. The idea of having a field that's just one crop is not what the native people traditionally think of. I asked my Hopi farmer friends why they don't do that, and they said, 'You can do that in a place where you've got lots of water.' But here they have fields–they're still small fields—and it's mostly all corn in that field, and then they'll have a bean field in another place, and then they have their peach and their apricot trees, and then lots of other sort of garden vegetables that they're growing too. I grew up in Illinois, and compared to those huge fields, Hopi would think that's ridiculous. They do small fields, and the fields will often shift, because it's mostly sand that they're growing in, so if you've got one area that starts getting depleted, you need to move to another field.

RM: So, could you say that the fact that the beginning of monoculture and agriculture is associated with a population boost, that it was maybe a boost in population that forced them to

really focus on that one crop and just expand it?

LY: I don't know if, traditionally, native peoples are ever really focusing on one crop. When I think of monoculture, that's really not possible until you get the mechanization of agriculture anyway. It's post-industrial revolution when you've got huge tractors that can turn up lots of land. What we do see happening archaeologically is that corn becomes a more important part of peoples' diet, but its never the only thing that they're growing. In part, also because these people don't have federal crop insurance, you've got your plot of land and you've got to feed your family on it. The strategy is not to maximize production, but to optimize production. Hopi are actually very dependent on corn, it's probably 60-75% of their diet. They plant a variety of crops but they're planting their crops in different fields at different times so not every field will probably produce, but *something's* going to produce, because we've got one near a dryer river bed, near an arroyo, and one in the sand dunes, scattered around since the rainfall there is so spotty. Their crops are really well adapted for dry conditions.

"The strategy is not to maximize production, but to optimize production."

RM: Is there any archaeological evidence, though, of these diseases that just wipe out crops?

LY: You know, it would be hard for us to see archaeologically. What we do see in the southwestern United States is drought. There were some really bad droughts at the end of the 1200's. We see people migrating from the Northern Southwest down to better water areas and figuring out how to farm by very long rivers, which are very tricky to farm, instead of the smaller streams. With those droughts, it affects not only the agriculture, but also that mixture of wild resources that people are still continuing to eat.

The other thing that happens is that Hopi is growing corn that's four different colors. They're doing that in part for their ceremonies, but there are subtle differences in varieties in the genetic composition of them, so they're growing a diversity of different types of corn. They're growing flint corn, dent corn, flour corn, corn that's easy to grind versus corn that has a really hard outer shell which is harder to grind but stores really really well… so it's diversity within species too. Not only just the different types of crops. For many of their religious ceremonies, you need the four different colors of corn, so there's this religious aspect that's keeping that diversity going.

RM: I would be interested to hear your opinion on the huge monocultures that we have now, and if you feel like the people that own these monocultures could learn anything from the past.

LY: I really like to eat locally, and those are some of the choices that I make with my own food. I think I probably mentioned in class that I'm vegetarian. The reason I became vegetarian was because it was my move towards anti-factory farming, and I became vegetarian over thirty years ago, so it was just at the beginning of people realizing that their chickens were produced in these huge factories. Many people didn't know about it at the time. Over the years I've also been shifting more and more to trying to get more of my produce locally too. It's harder this time of year, but I still try. That's been my real critique of agribusiness in particular, which I associate with those huge mono-cropped fields. I do think that if we took the total cost of what it takes to produce corn and soybeans in those big fields where they're putting so much pesticide on them,

or they're growing the crops that are Roundup ready, that we would realize that it's actually a really expensive system, and that if we took the perspective of taking care of the land, like I've said, rather than maximizing the production out of it, that we would be in a better place 50 to 100 years from now in terms of our agriculture. I think that is what people can learn from archaeology: how people make it work with little bits of labor, being able to live in a place for over 200 years, when I don't know if those big farms in Illinois are going to have that type of longevity, or if the land is going to get really tired.

One of my favorite stories from the area where I work is that, in the time periods that I look at, people are living in those sites for roughly 200 years at a time. This is by that Little Colorado river which can be very unpredictable and hard to farm. The Mormon settlers came in the 1800's, and they had their Midwest philosophy of, 'We're going to dam this river, we're going to grow wheat, we're going to grow sorghum for molasses,' and that's what they did. They built their little forts right in the river valley right next to it. They lasted ten years with that perspective of, 'We're going to control the river.' When there's a big rain up in the mountains, the water comes down and the river channel may move a half-mile away. So they put in their irrigation ditches, and all of a sudden the river's over there, and not near their fields at all. They didn't last with that farming perspective, whereas the native people that were used to being on the land, having to make a living that way, had figured out how to work with the land and how to work with the river instead of trying to control it and get as much out of it as they could.

Rebecca Emery: In response to increasing food needs as the world population grows, do you think that people will turn more to this type of practice where you have a diversity of crops versus the large-scale farming, because you're not just relying on one crop that may fail and leave you with nothing?

LY: I don't know if you guys have seen Catherine Badgley's website at all? She's a paleontologist but she studied organic gardens, and she has been teaching some classes on food. She actually did a study where what she argued is that the small-scale organic farming practices - taking care of the land, really thinking about how to get the most - you can actually get reliable crops, and a lot of crops out of it. She compared that, production-wise, versus production where you take out the cost of fertilizer that's put in, and the petroleum that you use for the tractors and all the equipment, and she found with those small-scale farming techniques, she could get almost as much production out as the big mono-crop agribusiness farms, and her land was in a lot better shape. Those farmers knew that they could pass that land on to their kids, whereas with the mono-cropping I think that land's going to be in really bad shape in years to come. I think we could feed the world in a lot healthier way than we can with the big agribusiness farms that we're using today.

I don't know if you've ever driven through Pennsylvania and seen Amish farmers there? What Amish farmers do is they have several rows of corn, and then they'll have a little barrier of hay. And then they'll have several rows of something else, and then a little barrier of hay. And so they've separated their fields so if one gets hit by some sort of blight, it won't take out the entire field. I really do think that it makes it more time-consuming to harvest, and probably to plant, but a little bit of time to be able to have a little more guarantee that you get something out of those fields I think is really important.

HW: Lisa Young's knowledge about early agriculture laid the foundation for our further discussions. After speaking to Dr. Young, we contacted Catherine Badgley to learn more about her research. Catherine Badgley is a professor at the University of Michigan, perhaps most well

known for her 2006 report comparing the yields of organic versus non-organic agricultural methods.

RM: One of the big concerns right now regarding single-crop monocultures has to do with their susceptibility to pest infection and disease. For instance, the recent banana scare has demonstrated that a single fungus, virus, or bacteria can wreak havoc on large plantations of genetically identical crops. From your point of view, do you think it is reasonable for large industrial farms, like those commonly found in the United States, to go back to more traditional ways of farming? Do you think there is a way to improve our current use of monocultures?

Catherine Badgley: If I'm understanding you correctly, what you mean by monoculture is low genetic diversity?

RM: Exactly.

CB: Because monoculture also suggests that a crop is grown by itself, and that is a slightly different issue. Another is a matter of what we call the actual genetic diversity of the crop, and there is no question that over most of the world's major crops, there has been a narrowing of genetic diversity in the last 100 years - a tremendous narrowing. But you're quite right, it does lead to potential huge vulnerabilities. Then there has also been, because of the prevalence of what you might call the 'Green Revolution,' or sometimes called 'Industrial Agriculture,' much more of an emphasis on growing plants, and even animals for that matter, very large amounts of a single crop in fields, which is what we call monocultures. And in principle, I suppose, one can be growing monocultures but have neighboring fields or farms with different genetic types, so you wouldn't necessarily have low genetic diversity within the monoculture. But the fact is that those practices have to a large degree gone hand in hand. And they have gone partly hand in hand partly because it has been a part of an approach to regularize, to make the whole management strategy quite predictable not only from place to place within a country but even between countries. That means that it's possible to market a whole management approach that has high predictability of outcome. It involves the genetic variety of the crop, it involves the manner of planting, the literal planting density, it involves prescriptions for how much fertilizer to use and when to fertilize, prescriptions for what kind of pest control and weed control, usually with synthetic biocides. And then, you know, how many days until harvest given the particularities of the climate and all that sort of thing.

RM: Yes. And often, when people speak about the benefits of monocultures, we think of this practice as an excuse for producing large quantities of food in order to feed the world. Is that why we usually have monocultures?

CB: You're right that that is part of the rhetoric within the whole system. When one looks into some of the details, you also see that once you standardize things the way I mentioned, where you have a very prescribed time to plant, method of planting and so forth, it is possible for one person, one person, and lots of machines to farm a huge area. That has certain kind of

attractions that has at least been promoted among farmers, particularly the United States and some of the others parts of the world as well. And saying, 'OK, this is going to be good for you because you, just you, all by yourself will be able to farm 500 acres, 1000 acres.' The problem is that this requires *enormous* investment of money, because these giant tractors, the plows, the combines and all that stuff, they can cost more than a house, and so people often become highly indebted in order to use this strategy. And once they've committed to it, you know, it's very hard to get out of it, because look at what they've invested now - not only have they bought all of this equipment, but they have to get that equipment out of the weather, so there has to be a big barn for the equipment, and there has to be fuel for the equipment. Once you start down that pathway, you've got a lot invested in it.

RM: Yes, I understand.

CB: So feeding the world is a very interesting question because if you look up all of the facts about where the food goes, the crops, particularly if we focus on the United States - what's grown in the largest acreage is corn and soybeans. But 70% of that is going to livestock - it's not going to people. I mean it's perfectly healthy food, but it's not going to people. And that is as of maybe, 10 or 15 years ago. Ten or 15 years ago, the federal government started a biofuel subsidy system that gave a lot of support for the whole effort to develop alternative energy sources. That now is diverting - taking a huge amount of the corn crop in the United States - corn to make ethanol. Because there has been funding for ethanol plants, it means the price of corn has gone way up, and it has meant that people who had farmland that was in conservation, a status where it wasn't being farmed at least in these row crops - it might be in some pasture usage or just left foul - they said, 'Forget that, we're just going to plant this because we can make so much money on corn now.' So it's led to a big shift in practices. But again, it's not feeding people if you look at the facts about where all this grain is going.

RM: Hmm, that is very interesting.

CB: Then there is this discrepancy that has been here now for decades, that if you look at how much food we actually grow worldwide, and often even country by country - even in countries that are very poor - you find that the amount of calories that are grown are more than enough to feed all their people, and yet there are still hungry people. Even in the United States there are very hungry people. It's not that we can't grow enough food, it's just that there is a big contingent of people that can't afford to buy food - to buy good food, healthy food - not junk food because it's cheap. And a lot of this food is cheap because it's made from all this excess corn and soybeans. Corn gets turned into high-fructose corn syrup in beverages and sweeteners, and then corn and soybeans together are made into oils and various things that go into making things like chips - very salty, fatty things. So, there are some very strong connections between food and what is called 'overproduce' - overproduced in the sense that if there is more supply than demand, then the price goes down, and there are constantly these surpluses. Well now we are kind of in an unusual place, where there are not so many surpluses because the biofuels have taken up so much of the corn. Now, the processing industry has also relied on huge input from corn and soybeans for it's raw material, for all manner of things. And a lot of this practice

is still going in that direction.

HW: This issue of poor citizens purchasing unhealthy food is also a heated topic currently with regards to the obesity epidemic. Are there any current programs in place that can help these citizens gain access to some of this surplus, or local food?

CB: There are integrative programs in various part of the United States, even in this area, such as a program called 'Double-up Food Bucks.' Here, vendors agree to provide double the value of food stamp credits or bridge cards for fruits and vegetables. What this means is that not only are you selling more to the people who grow the crops locally, but the people who need them most now have a greater ability to get them. People with low incomes can essentially be subsidized by society for purchasing food. This would be a temporary system while people are lifted out of poverty, but poverty has been a part of societies for a long time and changes in these societies that have been fundamentally altered have embraced change. However, the fault or full solution is not at the feet of the food system.

HW: So we see this trend of the farming industry heading toward alternative uses of the crops, such as for biofuels, but your research has focused on small, organic farming and how this practice has the potential, just like large industrial farms, to feed the world. Could you please speak about what you uncovered in your research and what the implications of your findings suggest for future methods of sustainability?

CB: Sure. This research actually grew out of an undergraduate class where we visited different kinds of farms, like those we call industrial farms, and we also talked with the farmers of these very small, non-conventional farms, about what they grew where they were trying different types of growing methods that rely much more on diversity. You know, rather than growing a single kind of corn, people might be growing several kinds of corn and they are growing that corn solely for human food. Sweet corn essentially, or things like popcorn and some of the specialty corns. But typically they grow several kinds of varieties, and they are growing food for other people - they're growing not just one kind of lettuce, but maybe 12 kinds of lettuce and 10 different kinds of tomatoes, and all the sorts of things you go and see at the farmers market in the summertime.

HW: Yes, I see.

CB: So anyways, we were at one particular farm with a farmer on a very small plot of land that had a huge number of varieties of crops, with sometimes just herbs so he could pick it himself in small quantities. Other times he planted things like lettuce that have a fairly short growing length, so he could get several crops per year. And we were just listening to all the different kinds of things he was growing, so we said to him, 'Have you ever tallied up how much food you're growing on this piece of land?'

To our surprise and pleasure, he said 'Yes I have, my assistants and I keep records, and so we know that on this plot of land (which turned out to be something like 3.5 acres where there was

actual growing), we had 27 tons of food last year.'

HW: Wow! That is a shocking figure!

CB: Yes, 'Twenty seven tons of food on 3.5 acres when you're growing things like lettuce that weigh almost nothing!' I thought. We were just stunned by that figure. And so afterward, we were discussing this statistic later, and we said, 'If he can grow that much food on that amount of land, why can't organic agriculture feed the world?' That question kind of lodged in our brains and we decided to follow it up the next year. So four undergraduates from that class plus a few graduate students and a co-teacher of the class, Ivette Perfecto, and I started to meet as kind of a little research group. We knew that some studies over the years that compared organic to non-organic farming, or standard industrial monocultures, must exist, as well as differences between the developed and developing world. Especially in the developing world, we knew there were studies looking at the traditional methods versus organic.

"If he can grow that much food on that amount of land, why can't organic agriculture feed the world?"

HW: Ahh, I imagine it would be interesting to look at the differences between first and second or third world countries, and perhaps even their definition of what organic means.

CB: Yes, and actually, many people don't know much about what it means to be 'organic.' They think that it's what farmers did 100 years ago when you take away synthetic inputs, but actually that is a very incorrect view. We wanted to look at research that observed differences in soil fertility, insects and pests, weeds, and practices developing varieties in polycultures, or fields of crops together in combination and what combinations do well together. Our take on organic farming now has taken advantage of research based on this ecological knowledge and is continuing to be developed, just as we are learning more about monocultures.

After we dug into the literature for about 6-8 months and compiled the data, we obtained data from both developed and developing cultures. In data from developed countries, we always compared industrial and organic farming, where the smaller subset from developing countries was always comparing traditional versus organic farming where the organic farming made use of more recent knowledge. We found data about plants and animals, and looked at some dairy farms, and decided to look at yield ratios to compare between grains, fruits, vegetables, and so on. We lumped the data into 10 different food categories taken from the Food and Agriculture website that has data for the entire world and even country-by-country. And within each category, you can look in greater detail. For example, grains can be broken into wheat, corn, rice, and some minor variations; vegetables can be broken into broccoli, asparagus, and so on.

HW: Does this site have information on different countries, or is all the data from the United States?

CB: No, this site allows you to aggregate country-by-country, continent-by-continent, and even in developed versus developing countries, and there is a lot of information about how the food is grown. So we plotted the yield rates from the different farms and they were not as different as we thought. In developed countries, the average ratio is 91%, meaning that organic farming produces about 91% of what industrial farms produce - almost as much, but not quite. In the developing world, there is a lot more yield for organic, and the reason for this is because when you are going from traditional to organic farming, you are going from well-developed methods that may not be using all the ecological knowledge we have now, like information on fertility and pests, so the yield increases with this added knowledge. Yield went up more than 100% in developing countries.

HW: That is quite a finding. So what does this mean on the larger scale and what are possible applications from this data?

CB: In answering the question, 'how does this scale up to the world,' we don't really know how or what it would be like. But, if we take the amount of food currently being grown, food mostly from industrial methods, and apply the yield ratio we can come up with a global estimate, using strict algebraic calculation of yield ratios applied to each different food category. And we get numbers representing huge amounts of food, which is hard to decipher for the average person. If you take the average diet we are currently consuming and convert it into calories and take the yield ratio multiplier which differs based on food category, we can complete one set of data for the developing versus the developed world. Our calculation showed that growing everything organically and converting this to calories, we will produce enough food to feed the world. We don't necessarily produce enough for everyone in the world to eat twice as much as they need, although this happens in some parts of the world. The recommended dietary consumption is 2000-2500 calories per day, and under our calculations from our stringent yield ratios for the developed world, if we suppose this applies everywhere, then organic agriculture would still produce approximately 2600 calories per person per day. The same calculation for the world's food supply coming out of the developing world and that coming out of the developed world, with the appropriate yield ratios for each, came out with over 4000 calories per person.

HW: That is almost double the recommended daily calories. So do you think that we can actually apply this to our current agricultural and farming system and perhaps make the necessary changes required to transition into organic farming?

CB: Well, we tried not to go too far beyond these conclusions because there are plenty of critics, so we kept close to the implications. We were very surprised and pleased with these numbers and we felt this data showed the numbers were good enough that organic agriculture could be taken seriously. Up to that point, in a lot of the articles about feeding the world (particularly coming out of the more conventionally minded universities and people), they said, 'Organic farming is a nice niche market,' and that it is good that we have a small organic section in food stores or farmers markets, but that it will never truly feed the world. And so we felt that our paper said, 'You're wrong - organic farming could feed the world and we have to take

organic farming more seriously.' And we do think that it had that effect. Our paper was cited by a lot of people, and a lot of critics that said we were not being realistic, that we haven't taken into account a lot of things. But people in the mindset of the industrial system think that that is the only way to farm, and maybe they haven't been around really productive organic farms or learned how it can be sustained. We had been to places in the United States and other countries, we had a number of organic farmers, without us ever asking them, tell us that they felt organic agriculture could feed the world because they saw how productive it was for them.

HW: There still seems to be this major divide though between those in favor of organic farming and those in favor of industrial methods. Why do you think this divide remains, and do you think that we can ever sway one side?

"Organic farming could feed the world and we have to take organic farming more seriously."

CB: Well, organic farming does take a lot of work - a different kind of work. It takes a lot less chemicals and in some cases less reliance on heavy equipment, and by some people, that is a bad thing. But look at how many people around the world are currently out of work. Why is that bad for a particular activity to require more work? But this also shows that the price of food is undervalued and that the price should be embodying the labor costs. The price of food would most likely increase, but this would be a good thing because it would be more valuable to be a farmer. Farmers would get more return on their investment. People then argue, 'But what about the poor people?' But what about the poor people right now! Food is highly undervalued, particularly in this country.

RM: Yes, I actually heard a statistic that in developed countries; people spend about 20% of their income on food.

CB: That is a very reasonable number, and one that can vary from in the teens to an even higher amount. In developing countries, that number is well above 50-60%. In the United States, it can even be as low as 10%. We are an anomaly, and so it is interesting to contemplate paying farmers minimum wage across the board and what that would do to our food prices. I think food prices would rise across both kinds of agriculture because we have a lot of underpaid farm workers.

RM: What benefits would the world have in changing to organic farming? What would be the major benefits, or perhaps what could go wrong?

CB: I think that among the major changes, it would take very different farm designs. The vast monocultures are not good at organic farming because they are susceptible to pests. There is nothing that a fungus or an insect loves more than 1000 acres of the same thing if that is it's food source. In controlling for pesticides, we need continual elaboration due to pesticide resistance, which is a very difficult, and almost impossible situation to get out of because of evolution. And evolution is quite rapid - these pesticides can build resistance at great speeds.

There is an ironic statistic that we use some millions of tons or barrels, or whatever we use to measure pesticide use, but that we have the same amount of pests as we did before we started using these because of both pesticide resistance and that the natural enemies have been devastated.

So, organic farming would require more small farms and a higher reliance on diversity. Not only spatial diversity, but also diversity through rotation: what's planted in one plot the first time is planted in a different plot the next time to break up the pest cycles. If what the pest likes to eat is no longer there, it will have to leave to thrive. One needs to break up big farms into smaller ones. Whether or not they are owned by the same person is not the issue, although this may be more of an economic issue, but at least we need to break up the smaller patches of crops so that the pests couldn't travel so easily through one larger area. This would mean taking a big combine of corn or wheat and working it through the back of a field to where, if you have to break up the fields into small plots with 20 different kinds of crops, the heavy machinery is no longer suitable. Then, all that investment has not been lost, but it has been drastically changed and is not easily converted to a smaller scale, which is why people are much more reluctant to think about changing to organic farming - because they have already invested so much in this other system.

HW: What would be some of the other benefits possible if we were to switch to organic farming?

CB: Some of the outright benefits would be that without pesticides, which can get into the food and water, or poison plants, animals, or soil organisms - that would all go away. This would also be a benefit for human health and ecosystems. If you suddenly convert monocultures, it really depends on the size of the system. If you have more diverse farms, you don't usually see one pest ravaging the whole thing. You would still get outbreaks, but they would be rare.

RM: So, what do you foresee about where we are going right now when it comes to agriculture and monoculture techniques? Have people started using the information you published or are most people still using traditional methods?

CB: I should just talk about the United States since that is what I know the most about, but no. I don't necessarily think that it is because of our research, but perhaps with the encouragement or confidence of our research, both farmers and consumers are practicing organic agriculture, but that is also partly because there is a good demand for organic food independent of whether or not people have read, or even know about, our paper. Our paper makes a difference potentially with policy makers that question whether we should be putting more research into organic agriculture. At the country or state or local level, we can question if we should be helping farmers markets that offer more opportunities to the small-scale farmers that are coming along. Michigan is a very interesting state in that it has had a growth in the number of farmers over the last 10 years - a change from the last previous 100 years where all farmers were declining in numbers. All that increase, or most of that increase, is due to very small scale farms that are doing more alternative things like selling through the farmer's markets or the weekly share of vegetables. Many of them are organic, not all of them, but many use at least

some of the organic principles. In the latest farm bill there was an increase in the money allotted for research for organic farming methods, and whether it remains a niche or whether organic gets bigger, there will always be a need for research. There is still a need for knowledge about how to manage pests, soil, and fertility. Organic farming is much more place specific than industrial agriculture because you can take the same recipe and apply it to several parts of the world, asking questions like: What is the growing season in this location? How is the soil? What are the native plants and species that eat the seeds? The plants in Michigan are different than those in Florida, and both are different than those in California or Kansas. We can also ask specifically what pests are going to be a problem? This approach is much more place specific, and so it needs more research.

HW: This has been a very interesting discussion! Thank you for speaking with us, we appreciate your time.

After speaking to Catherine Badgley, we were curious about what other scientists thought about her research. We got in touch with Jonathon Harrington, a consultant who advises farmers who want to increase their yields. He suggested we look at a report written by Alex Avery, which raises concerns about Badgley's methods. In Avery's report, he raises 5 main objections to Badgley's work, stating:

> This claim is simply not credible given the following internal fatal flaws:
> 1. Claiming yields from non-organic farming methods as organic;
> 2. Comparing organic yields to non-representative non-organic yields;
> 3. Double, triple, even quintuple counting of organic yields from the same few research projects;
> 4. Omitting non-favorable crop yields while using favorable yields from the same studies;
> 5. Misreporting yield results. [1]

Although this report cast doubts on her methods, Catherine Badgley's points were still relevant - more research on organic agriculture needs to be done. Moving forward, we spoke with Jonathon Harrington to learn more about the type of advice he gives to farmers nowadays, and strategies farmers can use to reduce disease, maintain genetic diversity, and lower costs of production.

RE: Hello Mr. Harrington, thanks for agreeing to speak with us today! Recently a herbicide-resistant strain of sugar beets was created and now 95% of sugar beets are of that variety. There's another paper that examines changes in crop diversity. For example in India, biodiversity has decreased because of the widespread adoption of Bt-cotton (an insect-resistant GMO variety). So would it be safe to say that biodiversity can be temporarily decreased by GM crops, but as new varieties are developed, biodiversity can increase over time?

[1] Avery, Alex. "'Organic abundance' report: fatally flawed." *Renewable Agriculture and Food Systems* 22.4 (2007): 321-29

Jonathon Harrington: I think you may be confusing varieties with traits. Do you know what a trait is?

RE: Yes.

JH: When you have a sugar beet, let's say there are ten desirable characteristics of the sugar beet. Might be yield, uniformity of crop, resistance to aphids or disease, sugar content. And then some bright person invents a way of making them resistant to Roundup. The likelihood is that the breeders will want to put that characteristic into all their varieties. So you have all those varieties with the new characteristic.

RE: I see.

JH: So you probably believe there's only one variety of herbicide-resistant sugar beet. I'd be very surprised if that was actually the case. Basically, you'll have ten varieties and that characteristic will be put into as many varieties as the breeders want.

Now when they further produce sugar beets in Europe they put the trait into old varieties and nobody would grow them. Because they were so old they didn't yield very well. So you need to check the trait against the crops. If you've got a desirable trait you want to put it into all the strains you can or that the breeders want to put it into.

RE: I see.

JH: What I'm trying to say is that if you have an old variety of potatoes and nobody grew it any longer because it got potato blight, if you could find a way of putting potato-blight resistance into it, it could come back.

RM: Does that mean that if we're growing beets with all these different varieties they can also interbreed?

JH: They can in theory. Sugar beet is a biannual. The first year the sugar beet grows a root and the second year it goes to seed. So in the US, normally it only goes to root because it is harvested, and never goes to seed. That's where you get the sugar from. Very few farmers grow sugar beet for seed, they grow it for root.

All I've got to say is that you've got some varieties of crops that you don't grow any longer because they've got some weakness that makes them impossible or undesirable to grow. If you could get a trait in them that would make them overcome that problem, they might come back again.

RE: On the same topic: you're probably familiar with the Cavendish banana which makes up 95% of banana production in the world. But they've recently been at risk from a fungus.

JH: That's right, Fusarium.

RE: Do you think that is an example of how limiting a crop to just one variety can make them more vulnerable to being knocked out by one pest or fungus?

JH: Exactly. It's called 'Black Sigatoka' and it's the most dangerous disease for the Cavendish. And the disease is now resistant to many of the fungicides we put on the bananas. So we can't spray for it. It's known as Panama Disease, carried by a fungus called Fusarium. Panama Disease rots banana plants and turns the fruits into a smelly, putrefied mess. There are no known fungicides for Fusarium and they can stay in the soil for decades and ruin plantations. One of the main reasons the Cavendish has been so successful has been because of it's historic resistance to the disease. For years Cavendish have been resistant to the disease, but it's suddenly broken down. Now this is called TR4 the strain of Fusarium. First identified in South Asia in the 1990's, TR4 has wiped out Cavendish plantations in South Asia and Australia. Last year it reached Africa and the Middle East.

In the 20th century, there was a banana called Gros Michel - its nickname was 'Big Mike'. It was by all accounts a far superior banana to the Cavendish: bigger, stronger and more delicious. Packers could throw big green nine-fingered bananas into the hull of the ship and they would emerge fresh, ripe, and undamaged on the other side of the world. The Gros Michel is what supplanted the apple as the United States' favorite fruit in the 1900's and defined the Western perception as 'top banana' or 'go bananas.' So what happened was that variety - Gros Michel - got Panama Disease and was almost wiped out. And then Cavendish took over. But the problem is that Cavendish is now going to go because of the next Fusarium. So we really need to try and breed a banana that is resistant to the disease.

NJ: So is Cavendish's falling apart a function of a new evolution of the fungus?

JH: Well it's probably that the fungus has mutated and it's basically able to overcome whatever resistance mechanism Cavendish had. Basically, most fungi in the world become resistant to fungicides at some point in time – some quicker than others. So I would say to you that this is all just an example of another variety that's evolved. Many of the plants we grow - wheat, barley, oats - they have problems with disease and these cause all sorts of problems. There are all sorts of problems going on from cotton to wheat to oats and so on.

RE: Are we forever doomed to be in this sort of arms race?

JH: The only way we could possibly make things last longer is if we reduce the disease pressure on them. If I can give you a quick example - there's an insect pest called the cotton boll weevil. In Australia they're growing GM cotton. But in order to reduce the pressure on the crops, they make all the farmers who are growing GM cotton put a refuge area around the edge of the field of conventional cotton. So you put your ordinary cotton that isn't resistant around the

edge of the field, normally 10-15% of the field, so that the boll weevils have somewhere to feed - because they don't like feeding on the GM cotton. And that reduces the selection pressure.

RM: Hasn't this become a norm?

JH: It has become common practice. This is not me having a swipe at the US, but when the cotton boll weevil-resistant varieties came into the US, the farmers were so enamored with them that they tended to plant large areas of them all with the same trait. Even if they grew two or three varieties, they all had resistance to the boll weevil. The problem with that is that if it only takes one gene to give them resistance, then you're back to square one again.

NJ: So this idea can be translated to stopping the evolution of fungi or other pests as well?

JH: There's a group of fungicides that are very widely used in the world called 'triazoles,' and they work by interrupting fat synthesis within the fungus. When I started working with these about thirty years ago, they were so effective that if you sprayed a plant, the tiniest amount of drift could control the fungus on the next plant because you only needed a tiny bit. But as the fungi became gently resistant, we found we had to use higher and higher doses and now that group of fungicides is a lot less effective than it was ten years ago.

"Nature will always win in the end."

My answer is, I think nature will always win in the end. The only way you can do it is if you take the pressure right off. Now organic potato growers, to try to avoid potato blight - have you heard of potato blight?

All: No.

JH: It's a fungus. Have you heard of the Irish Potato Famine? That was caused by a fungus called potato blight. I can give you the Latin name, it's *Phytophthora infestans***.** It's absolutely lethal. And it loves warm, damp conditions - just like they have in Ireland. The way the organic people do it is they plant their potatoes wide apart so you don't get a greenhouse effect. So if you plant your potatoes further apart, you don't get this sort of canopy in which fungus can develop. That's how the organic people try to reduce it. How do you think this affects the potatoes?

RE: Well the yield would be reduced.

JH: Exactly. But there are certain cultural methods we can do to avoid it. If you've got potatoes from last year and you just dump them by the hedge in the yard and they grow again in the spring and they're carrying the fungus, they're a source of infection. So basically farmers need to destroy all their old potato dumps to reduce the disease pressure.

RE: So in other words, there are other ways to reduce the effects of this that are pretty simple.

JH: If you look in a textbook for cultural methods. To give one more example, there are certain weeds that are a real problem in crops. For example, if you're trying to grow a grass crop like wheat or barley, you can imagine it's difficult to find a herbicide that will kill one grass type and not another. So a good technique is to prepare a seedbed before you plant the crop and leave it for a little bit so the weeds come up. Then you can spray them either with a weed killer that doesn't kill them all off, or you could cultivate it - plow it - so that you stop the weeds coming up in the crop. So that's another cultural method you can use that doesn't require pesticides and controls the weeds.

Some grass seeds will only germinate when they're near the surface. They have to see ultraviolet light. If you plow those out of the sight of light, they can't grow. So there are lots of cultural methods you can use to try and get around the problem.

RE: Could you talk about the genetic flow of favorable genes into neighboring weeds or plants?

JH: You have plants that are very closely related. Like canola is closely related to charlots. The Brassica family is an enormous family of plants. It includes cabbages, brussel sprouts, canola, rape, kale, calabrese. It's an enormous family and they're all quite closely related. And they have the odd problem where a characteristic has crossed into a weed. Now fortunately we have lots and lots of weed killers. So what one should be doing is not using the same weed killer every year. For instance, if you really like glyphosate resistant varieties and you use that, what you shouldn't do is keep using glyphosate resistant varieties because your weeds will eventually become resistant to it.

There's another herbicide called glufosinate-ammonium. It's a lot different than glyphosate but it's not unrelated. So if I was a farmer, I might grow a variety that was tolerant of glyphosate one year, but perhaps in the next field I would grow one tolerant of glufosinate to avoid resistance.

Now Dow, the chemical company, is trying to produce varieties of cereal, and I think cotton as well, that are resistant to dicamba. So what we ought to be doing is not using the same herbicide every year. We need to rotate. It's a bit like you being ill and using the same antibiotic all the time. It's not a good idea because eventually you'll end up with resistance.

Now on the subject of how you compare if you'll use more herbicide or less - it's a good question because there are lots of different kinds of them. I'm not sure what these are called in the States, but there's a group of them called sulphonyl-urea group. And they were developed by Dupont - very effective and very low doses - something like 20 grams an acre to control the weeds. But they've only got one mode of action. They tend to break down in resistance fairly quickly. Does that make sense?

All: Yes.

JH: So let's say you're putting on 100 grams per hectare - just for sake of the argument - and then decide you want to make a GM variety which is tolerant of glyphosate. Now typically, the dose of glyphosate, which is a different chemical entirely, would be 1000 grams/hectare. So you have to decide - is that a ten-fold increase in pesticide use?

It's a bit like adding apples and oranges together. Yes, you're using ten times as much, but it's a different active ingredient. If you go out for a meal and you have beans and someone else has a steak, and you have a pound of beans and they have a pound of steak - have you eaten the same amount as they have?

RM: It depends on the calories and energy you can get out of each steak, right?

JH: Absolutely, you have to be careful that you're not comparing apples with pears or oranges with lemons. When you say they're using ten times as much pesticides - yes, but what do we use ten times as much of? Can I compare glyphosate with one of the sulphonyl-ureas?

Here's another example. Do you know the toxicity of salt? Common salt?

RM: No.

JH: Did you know it was a poison?

RE: Well, I know it's not good for plants to be in soil that's too concentrated in salt.

JH: No I meant for human beings.

RE: Oh, no.

JH: There's a thing called an LD-50, the lethal dose to kill 50%. One of the things you would do in a toxicology practice is find out how much of something you would need to kill 50% of the population. The more you have to feed with something before you die, the safer it is. Well glyphosate has an LD50 of about 30x higher than common salt. This means it's very low in toxicity. You could probably kill yourself with it but you'd drown in it first. So then we need to decide - is using that amount of glyphosate worse than using a tenth of the amount of something else?

If I said to you, one of you has to eat a pound of oranges and one of you has to eat a pound of lemons. Who's going to go for oranges?

NJ: Me!

JH: And who's going to go for the lemons? They're similar but they're not really comparable.

RM: I see what you're saying. But what about resistance to pesticides? Are we kind of stuck in the Red Queen Hypothesis scenario?

JH: Every pesticide I've used in the last thirty years that I can think of is now showing signs of nature overcoming it. Glyphosate, which is one of the best, most effective and most broad spectrum, has its problems. There's a thing called Johnson's Grass in the United States that has found it's way around this. Every single thing I've been around - nature has found a way around somehow. Nature is a really clever thing and it won't give up. It'll get you somewhere.

You know how plants evolve anyway, they're evolving on their own?

RE: Yeah.

JH: They're evolving on their own and they will evolve. We won't outdo grass in the end - we're not that clever. All we can try to do is outmaneuver them temporarily.

RM: So could we just allow one type of crop to breed and develop it's own mechanisms of fighting off pests without pesticides?

JH: We could do that, but we'll have to wait years. There are several methods of plant breeding. You can take two varieties - say one that yields really high and another that makes fantastic bread - you can cross them.

Here's a quick story for you. The Victorians (this side of the pond), were frustrated that they were growing wheat that was suffering badly in the drought. There's another plant called rye, that doesn't taste so nice - it's a bit bitter - but it's tremendously drought-resistant. The other thing is that rye is very resistant to diseases like mildew, whereas wheat tends to get mildew. The Victorians - using a thing called culture-seed - managed to cross wheat and rye to make triticale. Now they hoped they'd have a nice bread making wheat that would be resistant to drought and disease. What they ended up with was a plant that was resistant to drought and was resistant to disease but was awful at making bread and was only good for feeding the livestock. Because you don't always get what you want when you cross things.

Here's a funny story, I recently did a talk at a Women's Institute. They asked me to come talk to them, and I asked a woman if she had kids, then if she got what she wanted. She said, 'I wanted a boy but got two girls.'

You can't even control what species you get. What we're doing as plant breeders is selecting crops for traits that we want. For example, nature doesn't want all its offspring to germinate in one go- it's for self-preservation. If they all go at one time and something happens - the cows go in or a nasty frost or snow - they'll all be killed off. This way you have more of a chance of some of them surviving.

But in agriculture, you want them all to come up together. So basically, we are selecting for traits that nature doesn't want.

RM: That kind of makes me think of the use of Monsanto crops, where they grow the crop and then they don't really keep it for the seeds. They completely take it away and then use new seeds that Monsanto gives the farmers. Is that a technique that you think we should avoid, or is that a good technique?

JH: There are two things here to grab - the scientific reason, and the commercial reason. The first thing is - if you cross two varieties of maize that are widely related, the first offspring you get would be F1. And with maize in particular, you get about five times the yield, bigger plants and so on. But if you cross the maize again, and you get the F2, then it will go back to what the parents were like. So you wouldn't want to keep the seed.

RE: I see.

JH: You would be better off buying fresh seeds. Certain plants work like that. With crossbreeding, you get hybrid vigor. With other plants, it doesn't happen like that. The commercial reason that Monsanto do what they do, is they spent millions of pounds developing these new varieties. And if you were a farmer and could buy one bag one year, and sow your field with it, harvest the corn, and sow the whole farm with it the second year, you'd only buy one bag, wouldn't you? Now, that's fine, but it means Monsanto wouldn't get their money back. So if you're a North American farmer, you sign a contract with Monsanto saying, 'I'll buy your seeds, but I'll sign a contract saying I won't keep any of the seeds, because I'll buy them off of you again the next year.' Now, if you don't want to sign that contract, if you say, 'I'm not prepared to sign it,' they'll say, 'That's fine, no problem, but we won't sell you the seed.' So all the court cases that have gone to court in the US and Canada, where farmers complained that Monsanto has spotted them or whatever, have been won by Monsanto. Because they've broken their contracts.

RM: So, I was also thinking - one issue that we often saw when we were looking at issues with monoculture was the sustainability of the crop and that the way the land is used can sometimes not be sustainable. But there's also this system which is having the crop in one place one year, and just moving the entire crop to another place. So is that usually advice you give to farmers, or is it just too much labor basically for it to be worth the price?

JH: Do you mean to say that you pick up all the crops and move them physically?

RE: No, in other words, year after year don't plant the same crop in the same exact place.

JH: Oh, no, I would agree with that entirely. You really shouldn't be using the same crop in the same spot ever. But there are certain areas that I hear are growing wheat all the time, but generally speaking it's not good practice. Farmers really should use rotations if they can, because you vary the pressures on the weeds.

RE: Right.

JH: Right. So just going through key traits for crop plants, generally speaking, if you're a wild plant, do you think you want to be tall, or short?

RM: Tall.

JH: I agree with you. The problem is if you're a tall plant, and you're in a crop, and the wind comes, you all fall over. The farmers want short plants.

RM: I see.

JH: If you're a plant, do you think you want to branch out to smother the weeds around you, or do you think you want to grow compact?

RE: Branch out.

JH: Correct. But the farmers want them to grow compact, so they can be managed more easily. Do you think you'd want the plant to ripen? If you're a wild plant would you want to ripen all together, or do you think you'd want to ripen over a period of time?

RE: Over a period of time.

JH: Correct. What do you think a farmer would want?

RE: All at once.

JH: Basically, the things that nature wants are not what farmers want. The whole time we're sort of fighting against nature. Now, for many of these traits that we want, we've managed to breed using other techniques. We use a thing called mutagenesis, which is where we put radiation onto a seed to make it mutate in the hope that we can get unusual characteristics. It's very slow, because it's like rolling a dice, hoping to get a double six. You've just got to keep doing it, and doing it, and doing it. And in the world, we only get two harvests a year, one in the Northern hemisphere, and one in the Southern hemisphere. So if you managed to breed a new pea variety or something, and you think, 'Wow this is fantastic, it's doubled its yields and doesn't get disease,' and you want to replicate it, you put the plant where you are in Michigan, and then to try and get two harvests you fly out to New Zealand to get another one. But it's still going to take you about ten years to get enough seed together to be worth selling.

RM: So is this going to be the technique of the future? To keep having new crops that are resistant to pests?

JH: I think we're going to have to try to produce crops with new traits. Can I give you another example?

All: Yes.

JH: There's a fungus that attacks wheat crops. Well, actually three fungi, three rust diseases (they look like rust because they've got spots on the leaves). One's called yellow rust, which likes damp, humid conditions - misty conditions. Optimum is about 15 degrees C, which is about 60 degrees Fahrenheit. There's another one called brown rust, which much prefers hot weather, dry weather, and that's optimum is about 70 degrees Fahrenheit. And there's another one, called black stem rust, optimum temperature about 30 degrees C. And they attack wheat. Now, most wheat isn't grown in the tropics. You grow it in the sub tropics. I suspect you grow it in Michigan?

NJ: Nearby.

JH: How often do you get to 30 degrees C in Michigan? Oh, sorry, about 90 degrees Fahrenheit?

RE: Oh, not very often.

NJ: A few times a year.

JH: Exactly. So how much trouble do you think the breeders have been in trying to make sure that the varieties they grow are resistant to stem rust?

NJ: Very little.

JH: Exactly. They haven't bothered. But they have been taking trouble to breed probably against yellow rust and brown rust. Now, a lot of the wheat in the world is grown around the Tropic of Cancer and the Tropic of Capricorn. But with global warming, those areas are getting hotter. Suddenly black stem rust is becoming a problem in wheat. And the breeders haven't been selecting for resistance to it. So we now have a problem. We've got all these varieties of wheat we like, but they've got no resistance to black stem rust. What are we going to do? Well, we could try conventional breeding, and hope we find a trait for resistance to it, or we could do genetic engineering. And genetic engineering is likely to be a lot quicker. So chances are, breeders are trying to use genetic mutation in some form to get black stem resistance into the varieties.

RE: So we just finished speaking to Catherine Badgley.

JH: Yes, I'm familiar with her work.

RE: Yes, so she's done research and is claiming that organic methods are just as productive as 'Green Revolution,' or industrialized agricultural methods. She says it is more labor intensive, relies more on human labor, but, in terms of calories, is able to produce enough food to sustain the world population. She acknowledged that her work has been kind of controversial, because it involves making these large global estimates, and who can tell if they're completely accurate or not. But I was wondering you could tell us about maybe some concerns you have in that approach of using just organic methods, and whether the benefits of using organic methods are worth the cost of changing all of our infrastructure to that method.

JH: Right. When your grandparents were around - would your grandparents be around in 1900? Or am I getting old?

RE: Maybe not quite 1900.

JH: They probably spent 30-40% of their income on food for domestic consumption. There weren't many McDonald's, there weren't any Kentucky Fried Chickens. Most people would eat at home, would that be fair? Because food was relatively expensive. Modern agriculture techniques have make food cheaper and cheaper and cheaper. Mechanical techniques mean fewer people work on the land, because people don't like working out on the land, weeding or hoeing and picking aphids off or whatever. That's why most of us live in towns now. Around 1900, there were around 1 billion people on the planet. Do you know how many people are on the planet now?

RM: About 7 billion?

JH: Very good. About 7.1 billion. So, we've got seven times more people on the planet now than we did 110 years ago. They all want feeding, believe it or not. Now, as a result of food becoming cheaper, I don't know if you know, but we waste a lot of food in the States and in Europe we chuck about a third of our food away. Do you know what percent of income is spent on food for domestic consumption?

RE: I think in the United States it's about 10 or 12%.

JH: You're on the button. Ten. It was down to nine at once, but it's up to ten again. Over here it's just crossed from 10 to 11. It's very cheap. So if people say to you, 'I don't believe you,' just point out all the McDonalds and the number of Kentucky Fried Chickens and the number of obese people around. So basically food has become extremely cheap, and people don't like working on the land, hand weeding planting potatoes or whatever. They like sitting at home and watching the television. So if we all prepared to stop changing our diets, stop eating meat and only eat cereals or vegetables and hand-weed the crops, I think she's got a point, Catherine Badgley. She's got a point. Do you eat meat?

RE: Yes.

RM: Yes, of course.

JH: Every day?

RE: No.

RM: It's expensive when you're in college.

JH: Ah good point. But we all like eating meat. And meat is a very inefficient way of doing things, because we basically grow a crop and feed it to an animal. And animals like cows and sheep are very inefficient in converting grains to the meat. Only about 10% efficient. So, I can see her point, but I can send you some work which does demolish the credibility of her work pretty badly. Now, I'm a scientist, and you should always make your own conclusions, but Dr. Badgley's work has been - how shall I say it - widely derided. I believe she's in employment of the organic food industry over there. I'll find out for you. Her views are regarded as - what's the word - contentious? She's a character.

Next, we talked about domestication of animals and plants, which, while interesting, will be omitted for time purposes. We pick up in conversation about ancient farming techniques.

JH: And about 10,000 years ago, the Romans discovered that if they dipped their seeds in red wine, they grew better. Any idea why?

RE: If there's a pathogen on the outside of the seed, you might sterilize it with the alcohol?

JH: Bullseye. Well done. There are various fungi that sit on the outside of the seed as part of the life cycle, and they found if they dip the seed in the red wine, which has got alcohol and tannins, it helped to kill some of the pathogens. They didn't know why, they just knew it did. Have you heard of the dark ages? When the Romans left Britain, most of the British couldn't write, or read for that matter. So within the next 200 years, it was all forgotten. The Romans didn't leave a notebook saying, 'All right lads, before you plant the seeds, dip it in the wine first.' So as a result, agriculture went backwards. Now, only African and European men had pack animals to help with the work. So that's why agriculture developed faster than it did over on your side of the pond.

RM: Is the point that there are already a lot of people and we really need this technology because we can't just go back to our previous methods that were not as effective and not able to feed us as much as we need?

JH: Absolutely and especially they are much quicker. I would say that the advantage of GM is that they are more precise - they are quicker and they allow us to do a few things we can't do with conventional techniques. In South America, there is a plant that is very closely related to potatoes, same family, but it doesn't get potato blight. And for the last 50 years people have tried to cross them with potatoes to get potato blight resistance into potatoes. And they failed.

They have now done it using GM techniques. Sooner of later nature will catch up with us. All what we can do is hope to be one step ahead of nature. All the time we are working against nature a bit.

RE: What other advice would you give to a farmer today?

JH: You want to grow a variety that suits your land. If he is in the middle of Canada and they have a short growing season, he is going to want to grow a variety with a short green season. Now, a variety in the middle of Canada won't necessarily suit the middle of Florida. So he has to use a variety that suits his conditions. So what I say is, be careful of the varieties you pick, make sure you pick a variety that is being bred for the conditions you live in. Now, would you be prepared to pay more for a GM seed? Well he might be prepared to pay more if it had some advantages. Farmers have to evaluate the high cost of certain seeds with advantageous traits against those of others. You can see, if the GM variety cost, say, 20 dollars an acre more than a standard one, will the crop be more advantageous to grow? Will the inputs be less or more? What will it yield? You would have to work it out. Be careful. Over here consumers will pay 10% more for organic foods, what is happening with organic food over with you?

RE: I think it is more than 10%. At least to buy.

JH: Do you buy it?

RE: Not very often.

JH: Over here it is about 3 to 4% of the market. People have to pay more for it and they buy it. But it has leveled off today. You never get more than 5%. What I never understood is that if I wanted to buy organic and I didn't want to spray insecticides on the crop and I could have a GM variety that didn't need to be sprayed by insecticides, then that would be a good idea. There are pressures from certain organic growers to have GM. Some organic growers want to have them.

RM: How do you foresee the future? Where are we going right now and what is going to change?

JH: We are going to have to breed varieties adapting to climate. Do you think your climate in the states is changing?

RM: We had a harsh winter with the polar vortex.

JH: Exactly, organic farmers had a problem with it because they get taken out by the cold. Don't they? If we could produce a variety that was resistant to snow, now that could work wouldn't it? In term of the world there are vast areas in Australia that are just drying up like really bad, they are desperate for drought resistant crops. We are not doing very well with those so far. So I would say how fast should companies change their policies before we lose an entire food variety? For example, with the GM bananas. Plant breeders will afford a new variety if they can

see that they will sell the seed. If you are a plant breeder that say, makes a new variety that makes purple wheat and no one buys it, you are stuffed, aren't you? So there needs to be varieties that people will buy. Do you know about Amish farmers? They have adopted GM plants. They have been persuaded by Henry Miller to adopt it although they still use horse and cows to plow and won't have tractors they adopted GM.

RE: Thank you for your time.

HW: Mr. Harrington brought up many interesting points with regards to our struggle to harness nature. In addition, he explored some of the problems farmers have faced over the years and their solutions to these problems. Many of these solutions were natural, but some of them relied on chemical aids like pesticides. Our next guest, Bill Hewitt, will now talk about how our attempts to control nature have had observable consequences on our planet, and what could be done to minimize the damage.

NJ: What is your opinion on how monocultures are affecting agriculture and it's economic and climate effects? What are your general thoughts on the topic?

Bill Hewitt: My general thought on the subject is that it's all about the commercial value of the crop and it has almost nothing to do with the value of the land and particularly the soil and the water and the livelihoods of the people who live on the land. That's my general take.

We see tremendous degradation of soil, we see impacts on biodiversity, we see people being destituted as a consequence of agribusiness and how the concentration of growing single numbers of crops, corn and soy in the US are probably the biggest culprits. We see all the attendant problems of this hyper-industrialization of what has been for 15,000 years something that small-holders do with traditional methods and generally without chemicals and, historically, generally without a whole lot of irrigation. So that's my general thought.

NJ: Could you speak more specifically to monocultures' effects on biodiversity?

BH: I would look at it from a different point of view. Yes, there are very specific strains of soy and corn and wheat that we use, certainly, in American agriculture. But, I'm thinking more in terms of land use and individual crops that can get in and destroy land use. My example of the destruction of land in a monoculture would be the palm oil in Indonesia and also in Malaysia. This is fairly well-documented that when you're cutting down rainforests and you're drying up peatlands that you're inflicting havoc on all kinds of animals and plant life that have been living and developing and evolving in that ecosystem for millions of years in many cases. Palm oil in Indonesia is one well-documented example of this destruction.

NJ: Could you speak about the climate implications?

BH: We're looking at various impacts. [Cites an OP/ED from NYT "Corn For Food, Not Fuel"] About ⅓ of corn in the US is used to feed livestock. Forty percent is used to produce ethanol, 13% is exported - almost all for feed for livestock. The rest goes somewhat to sweet corn that we enjoy in the summer, but most of the rest goes to high fructose corn syrup - which has it's own attendant problems with very cheap sweeteners in the American diet. How do we grow all this corn? We grow it with nitrogen fertilizers, and these fertilizers have a tremendous climate impact that comes from the fact that nitrogen is not fully taken up by the plant as it grows, so it becomes volatilized into nitrous oxide which is a greenhouse gas that is 300 times more potent than carbon dioxide. It has what is called a "global warming potential" - over 20 years in the atmosphere and 300 times that of carbon dioxide. Globally, according to the UN Environment Program, agriculture is responsible for 15% of our approximately 48-50 billion tons a year of carbon dioxide. So of the 15% agriculture is contributing to that total, nitrous oxide is responsible for about half. That's coming almost wholly from nitrogen fertilizer run-off. You don't grow all that corn or soy without the nitrogen fertilizers.

Corn Usage in United States:
- 40% Ethanol
- ~35% Livestock Feed
- 13% Exported
- 12% Food & Beverage Production

Carter, Colin A., and Henry I. Miller. "Corn for Food, Not Fuel." *The New York Times*. The New York Times, 30 July 2012. Web. 10 Apr. 2014.

NJ: So what you're saying is that much of the fertilizers we are using today are not only harmful for the environment now, but is something that will continue to affect the environment for years to come.

BH: Exactly. And if we follow the line back, we're using this corn for ethanol, feed for livestock, exports and high fructose corn syrup. What you see is massive amounts of land that are devoted to feed for livestock.

NJ: Yes, I see.

BH: Let's look at two other countries now - Brazil and Indonesia. Going back to that 48-50 billion tons a year of carbon dioxide equivalent, the World Resources Institute has a very good online tool looking at how and where we produce our greenhouse gases. When you look at a country like Brazil, you'll see that Brazil is responsible for a total of 4.6% of total greenhouse gases produced in the world in 2010. Why? It's because billion tons of these gases are coming from land use changes based on two reasons: cattle and soy. Although it is really three things, there is also sugar cane ethanol. Because, as you're aware that Brazil has a very successful program going back decades producing sugar cane for ethanol for their transportation.

NJ: Sure.

BH: I would say the other good example of land use change is again the palm oil in Indonesia. You look at Indonesia's numbers relative to the total in the world and Indonesia's responsible for 2.5% of the greenhouse gases that we produce annually in the world. You don't think of Indonesia as an industrial country, like China with big industrial coal plants churning out all the

world's stuff or a rapidly, massively growing transportation fleet using petroleum based foods. China's responsible for about 22% of our greenhouse gases now and the US is about 14.5%, but then you get to Brazil at 4.6% and Indonesia at 2.5% and you're still talking about considerable amounts of greenhouse gases almost all of which comes from land use changes driven by agriculture. So in a sense, beef cattle is a monoculture, essentially, as is the soy in the Serrado and palm oil in Indonesia. These are all high economic value products and agribusiness driven products. All that soy from Brazil goes to China to feed pigs. So those are some of the climate implications.

NJ: What do you think is the root of the current problems related to agriculture - big business, government regulations, or a result of increasing demand?

BH: Who would argue against affordable, nutritious food? None of us. None of us could or would or should, I hope, argue against developing nations' access to nutrition. We've lived with malnutrition and famine in parts of the world for the entirety of human history. It's a great thing that we're able to produce more food, however the environmental implications have a lot of people, and I hope more and more, stepping back and asking, "Are we doing this the right way?"

I think you're really asking two questions: why does this happen? And does it need to happen? How does it happen - in the US certainly - politics and the influence of special interests, agribusiness, play a huge role, obviously. I would refer you to people like the Environmental Working Group, who do fabulous work and are based in Washington and know all the in's and out's of the Farm Bill and how the agribusiness interests play. In the federal system that we have, a tremendous influence, and for that matter in the E.U. as well, farmers have huge political influence. The farm lobby has huge political influence - we would not have seen the growth of ethanol, even though it's really counter-productive to its stated aim of reducing reliance on oil for transportation - it doesn't even work that well and it will screw up your engine. I'm not an automotive guy but from what I've read, ethanol isn't the best thing to put into your engine. So the influence of the farm lobby is really critical in this, and the subsidies ethanol used to get and don't get in the US anymore, and the tariff on ethanol from Brazil, certainly kept the ethanol business fairly healthy.

NJ: So how is the economy affected in all of this?

BH: I would also refer you to several studies, one of which the World Bank of Food and Agriculture of the UN commissioned about 10 years ago, in what's called International Assessment of Agricultural Knowledge Science and Tech for Development. They took 400 agricultural scientists to look at how we do farming in the world and why, if we have so much of what appears to be productivity, there's so much of a gap in feeding people. One of the quotes I use from that study is "productivity increase has come at a cost: environmental sustainability. Soils, water, biodiversity and climate change" They further say in order to increase farmers' natural capital and thereby increase long-term flows in terms of farm outputs, modifying the management of soil water and vegetation resources based on agro-ecology, conservation

agriculture, agricultural forestry and sustainable rangeland and forest management as well as wildlife biology and ecology has been supported. And then there was another report from the UN, they have what are called 'raporters' and they do special reporting on various subjects and he was writing about food security and in essence, this report was from 2010, agro-ecology outperforms large-scale industrial farming for global food security. These are extensive studies that were done that show that one can do these things differently. And it's obviously much more to the benefit of small holders who can't and shouldn't have to afford pesticides and fertilizer and fungicides and all the other chemical inputs that appear to be necessary but really aren't at the end of the day.

RE: What are your thoughts on GMOs? I've read that there are plants that are able to do their own nitrogen fixation from the air. Would investing in plants like this help alleviate some of the problems, such as keeping out of forests?

BH: My short answer to your question is, 'Yes.' My take on GMOs is simple: if we can develop crops that, as you say, can fix nitrogen from the air or that are more drought or heat-resistant, given the conditions that we are clearly going to face and are facing in much of the world now as a consequence of climate change, I think that's all good. My understanding of the state of GMO production is that most of it is devoted, at this point, to things like Roundup-resistant crops so that companies like Monsanto can sell you their seed, but it will still have to withstand all the pesticides, but that's what they're meant to do. So the pesticide 'hit' to the soil is still there. You're still going to destroy all the incredible, important, and billion-year evolved microbial capacity of the soil in applying that pesticide. If you can have these freestanding GMO crops then great. I have been to at least one symposium at Columbia University at which experts were having this conversation and the consensus seemed to be that GMOs weren't inherently destructive or risky according to pretty much all field studies.

NJ: Do you see anything in the news that points to this issue?

BH: Yes, the Intergovernmental Panel for Climate Change, the Second Working Group Report from last week, came out with information where the impact, adaptation and vulnerability to food security was for the first time highlighted. Climate change, as you know, is causing havoc in terms of rainfall - too little or too much. These are long-term trends that are going to continue, and if we continue to do agriculture in the way that we do it now, we are going to continue to produce greenhouse gases. On the flipside, and I think what pretty much everyone working in sustainable development these days understands is, as we deal with the impacts of climate change, as we adapt, we can reduce our greenhouse gas inputs. Agriculture is a perfect example of how we can do this by reducing the chemical inputs, by diversifying, by using agro-forestry, agro-ecology. And you'll see in the next two or three weeks, the Intergovernmental Panel on Climate Change's Third Working Group Report on mitigation. And there will be a lot of information available on how we cut back on our greenhouse gases, as well as agriculture. And this is pretty current stuff.

NJ: Where do you see the future of farming going in the next 20 years?

BH: I would like to think I see it going in the direction of organic. I'd like to think that it's going in the direction of taking back the land as it were, and that this would be happening globally. One of the other things that I got from [a colleague] was a reference to the Organic Farmers Action Network - they are doing a lot of work to advance this. But there are farmers around the world who recognize that their livelihoods don't rely on big export - that they rely on quality food, not at the expense of the land on which they're living.

La Via Campesina is an international movement and I think groups like that and like the Rainforest Alliance, which has concerns regarding biodiversity among others, is very involved in working with small-holders and communities in South America and Asia and helping people get back to traditional farming techniques, which worked *and* worked very well - everywhere from the US to Europe to emerging economies in South America and Asia. People are seeing the benefits.

The other thing is - who's buying? I think things like community supported agriculture and farms seem to be a growing trend, on an upward growth curve, judging by the increase in stores like Whole Foods and even the fact that a company like Wal-Mart is becoming more interested in produce and even organic produce. This is true in Britain, certainly. In France, they use the word 'Bio' on the label and that essentially means it's organic. So as far as consumers go, and at the end of the day that's where the money is, that's hopefully a positive trend.

HW: After Mr. Hewitt mentioned current movements like the Rainforest Alliance, and pointed us in the direction to consider the consequences of farming on land and people, we contacted Simone Lovera, director of the Global Forest Coalition, to give us her point of view on monocultures with a focus on both a global and local scale, especially in Paraguay. Her organization fights against large agribusinesses that implant vast tree monocultures surrounding indigenous communities, and her work focuses mainly in protecting the rights of these natives.

RM: How did monoculture get introduced in South America?

Simone Lovera: Timber producers started to look at the introduction of timber production in the forest. They gradually started introducing clear-cut practices, in which they basically cut the entire product forest, and the easiest way to re-plant it was to introduce a monoculture tree plantation. This has gone on massively, especially in Northern countries, throughout the 20th century. So as a result, a lot of original forests have been replaced by monoculture tree plantations. We actually have a little case study I wrote from a Dutch perspective about a plantation where my parents lived. I did real research about how these things happened in the area where they lived. There used to be people around there, but they had to leave because there was no work anymore and all the land was taken over by these monocultures. Lots of local communities got kicked off their land because monoculture tree plantations provide very little labor, and they lose a lot of jobs. We can see this worldwide when these monocultures

come, especially when they're genetically modified. It tends to be genetically modified to require less labor, so it also means people are kicked off their land. The saddest thing about land grabbing, because there is a lot of interest in land grabbing these days, is people feel surrounded by these monoculture that don't give them any jobs. Other people leave, and they can't send their kids to school anymore, the shops close down and it becomes impossible to continue living in that village.

RM: So if I understand clearly, the main issue with monoculture practice is that it requires less labor and people get indirectly kicked out of that area because they cannot find a job and everything around them shuts down.

"People feel surrounded by these monoculture that don't give them any jobs, other people leave, they can't send their kids to school anymore, the shops close down and it becomes impossible to continue living in that village."

SL: Yes, and from the environmental side, all is extremely negative, as well. Monocultures are much worse for the climate and most come with massive amounts of pesticides. Eucalyptus and pine monocultures lead to acidification of soil, contamination, desiccation, and a lot of communities are left without water streams. There is a whole range of negative impacts associated with monocultures. One tricky argument that is often used in this respect is, 'it is not a problem because we only plant on marginal and degraded lands.' No! Marginal lands tend to be very biodiverse, rich land where marginal people live. Because of sociological patterns economically and politically, marginal people often have been moved throughout history to what is often called marginal lands, and that is where a lot of indigenous people live. So you are talking about the most vulnerable population that are most impacted by this monoculture expansion. Another big misunderstanding is the term 'degraded.' This is a big scientific misunderstanding. Degraded is a relative term. Ecosystems are more or less degraded. They can also be more or less restored. By definition, every hectare of land on this planet is a potential restored ecosystem. In some cases, where it is very degraded, you will have to wait 1000 years until it comes back again, but you know every hectare on earth has been evolving from one ecosystem to another ecosystem, and it can reach its prime again if you don't use it. There is no such thing as a land that is degraded and can't be used for anything. You are talking about a potential ecosystem, or in most cases you are talking about a potential forest. A lot of monoculture tree plantations have been planted on massive deforested lands that would have grown back again if they weren't taken over by monocultures for agrofuel or other crops.

RM: Do these companies use any techniques to prevent severe damage to the soil? In a previous interview we discussed crop rotation, which seemed to be useful in promoting soil health.

SL: Crop rotation is a technique that is traditionally used that is definitively worthwhile. In fact, organic agriculture in northern countries recommends intercropping or changing crops. However, it must be done in a very extensive way if you want the forest to recuperate in the meantime. So you are talking about at least 20 to 40 year intervals; that time is not given. It is not necessarily coming back to climate biodiversity even with these intervals, as some species won't be able to survive in such a system. The key issue is how much land is needed and how much production you want to produce. We at Global Forest Coalition focus on land use in general and totally reject bioenergy expansion. The last thing we need on this planet is to only produce energy by our land. There is already not enough land to produce food while maintaining enough ecosystems. We definitely don't want to waste land on producing energy since we can much more efficiently do that through solar and other techniques. This relates to unsustainable livestock production, unless you do it in a totally integrated way with the land - which is possible. It requires massive amounts of land for food that is subsequently wasted because it produces only a fifth of the proteins that you could consume if you just have a plant-based diet.

RM: Would you be against GMO monocultures if they were designed for less pesticide use and were therefore less harmful to the soil?

SL: The dynamics of industry will always work toward more pesticides because they won't make a lot of money if they cut that. It will be like cutting their own flesh. The industry also needs to get money out of the seeds themselves, so they will never allow farmers to use their seeds to produce better varieties. It will always be subject to intellectual properties rights. The most important thing, especially with genetically modified trees, but also genetically modified crops, is that there is a tremendous amount of risk and we don't have any legal system in place to really deal with those risks. There are people who have been sued by Monsanto because their fields were contaminated by genetically modified crops. It is a pathetic system! I was a member of the National Seeds Advisory Board in the Netherlands, and I will never forget the head of the biggest seed bank in the Netherlands saying loud and clear, 'Genetic modification is nonsense. We have already succeeded in getting so many varieties in agriculture through traditional breeding practices. We don't need genetic modification. We have crops against diseases. We can all do it all conventionally. We don't need to take the risk of genetic modification.' Genetic modification is a symptom of big industry. You wouldn't need genetic modification if you had sustainable practices, but because the industry is working more and more with monoculture practices, it is much more susceptible to diseases. They are only modifying organisms to produce a lot more biomass without any consideration for biodiversity, environment, or social aspects. So the whole technology is serving very strong commercial interest of a very strong commercial sector. GMOs were invented to just serve profits.

RM: How would you change current practices? Is there a possible compromise between these agribusinesses and the Global Forest Coalition?

SL: I don't know if I can find a compromise with these companies to keep growing their crop. There are a lot of very sustainable examples and that is the great news. We are working

together on this consideration on territories conserved by indigenous people in local communities. It is estimated that up to 22% of terrestrial surface is covered by territories and areas conserved by indigenous people and local communities. There are massive areas of land that are formally indigenous territory and they have succeeded to conserve that for centuries and they don't depend on increasing profit. In some indigenous cultures this is not eroding, you do see indigenous people getting absorbed into certain industrial structures, but they are still a very lively example of sustainable agriculture. In countries like Paraguay, there is a century old tradition of small scale agriculture without need of pesticides - just making use of the richness of the land and on a small amount of the land so that you don't need mass expansion and deforestation, and there was full food sovereignty already two centuries ago in this country. The issue is that people make a lot of profit and the agro-industry has been taking this over so that they can just make money out of peoples' lands and peoples' hunger. They have done it in such a way that they've completely worked the food system. You now have more than enough food being produced to easily feed the entire work population, and there are still one million people hungry. That is the scandal of the century! These agro-industries have not succeeded in feeding the people while they pretend to do so. Why do they not do that? Instead of growing food for the people, they grow soy for pigs in Minnesota that are subsequently turned into hamburgers that poison people instead of feeding them. A lot of food is wasted. Food waste is often thought of in terms of rotting, but the biggest food waste is in producing products that are not contributing to people's nutrition. Animal protein is useful in a diet but very little is needed. Eighty to 90% of the animal protein the people eat in northern countries is wasted, because if you eat too much animal protein, it only makes you sick. And of course then there is the Coca-Cola, all the alcohols, and a lot of things that people drink and eat that waste a tremendous amount of resources that are happily produced by these agro-industries and contribute nothing to people's nutrition. In the end, it is the food system. A lot of malnutrition in the world is also due to social patterns - it is very much gender based. Women suffer far more from hunger than men, and producing massive amounts of food hasn't helped.

RM: Could natives replace the role of agribusinesses and distribute their crops around the world?

SL: Well, they could produce enough food for themselves. I don't know why South Americans would have to produce food for other regions. They very much believe in local food sovereignty, so food systems should as much as possible be based upon trying to produce food for local markets. There is of course a sociological analysis that rural areas tend to be areas that have relatively less education, economic and political power. So the majority of the farmers are in a

weak sociological situation and can be very easily exploited. This means that in any international market they will very easily be marginalized and left out. The overwhelming majority of small farmers have been totally squeezed out by national food markets. We are working very closely with La Via Campesina, which is by far the biggest global movement representing millions and millions of small farmers all over the world, and they have a very strong position to get agriculture out of international trade negotiations - to stop liberalizing agriculture, but to instead strongly protect global and national food production

"The majority of the farmers are in a weak sociological situation and can be very easily exploited."

RM: In which direction are we going? How do you foresee the future?

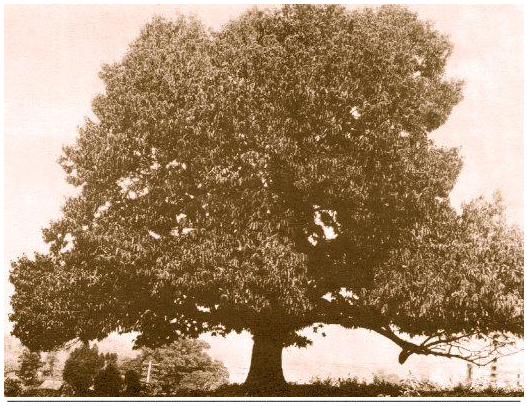
SL: The good news is that, at least in agriculture, there is obviously a growing awareness among governments. They have realized that industry lied about monocultures helping people and being planted on degraded lands. Negotiations, in which we are very much involved, called the Post 2015 Agenda to discuss a new set of government goals. In those negotiations we see a lot of government also saying they need a radical change in their agriculture food system. I must say that the present movement of La Via Campesina, and also other food producer movements - for example fish workers - have really helped in promoting that agenda. I do think that there is a basic awareness among governments that things need to change radically. That said, here, we have a new government since August and they are the most dreadful. The new president has been a soft drinks producer. He just thinks that any kind of production is fine - he doesn't care at all about environmental contamination or about small-scale producers. He is just about making as much money out of this country as possible. That's why you see very much the opposite trend and he has literally said people should come to Paraguay to use its land and abuse it. He has been quoted on that in the news. You have those presidents that really do not care at all about their own country and that use this agro-industrial system to make as much money as possible.

RM: Thank you, Ms. Lovera.

HW: Through this interview we've learned that monocultures implanted by agribusinesses can have very negative impacts on human rights and the environment, as they can easily take advantage of the natives who live around the land. Yet, is this an issue linked to monoculture or agribusinesses in general? Is there truly an advantage concerning the environment, human rights, and less risk of losing an entire food variety if a crop with high genetic diversity was cultivated? Could these issues be solved using biotechnologies? To answer these questions we interviewed Dr. Prakash, a professor of Plant Molecular Genetics at Tuskegee University, who has served on the panel for the USDA's Biotechnology Advisory Committee.

RE: Will GE crops accelerate the trend towards fewer varieties of crops? Will not such a loss of crop diversity make agriculture more vulnerable?

C.S. Prakash: This is important because you're asking about the issue of monoculture. The best way to answer that is to recall my visit to Michigan State University in East Lansing. It's a beautiful campus. That's the first time I saw the great American Chestnut tree. That's the only place where you will see it. Some of the older people will tell you that almost every third tree in the United States in the 30's and 40's was a chestnut tree, and they all disappeared. Every one of them. By some estimates, there were more than 1 billion of those trees all over the eastern United States, and they're all gone because of one fungus. Why I'm saying that is, chestnuts had tremendous genetic diversity. And they were natural, we didn't plant them. They were here for millions of years, and in a span of ten years they were all gone. That tells me two things: First, there is always genetic vulnerability, and secondly, genetic diversity itself is not a great protection against an epidemic of disease. Even with all the diversity, we lost the chestnut.



"Genetic diversity itself is not a great protection against an epidemic of disease."

But what we need to recognize is, in agriculture, there has been a gradual erosion of genetic diversity throughout the 20th century. I grew up in India, where we used to grow literally thousands of varieties of rice. That erosion started with the onset of modern agriculture and modern varieties. The advent of GMO varieties has not accelerated it. It has been a reversal of trend of that erosion, primarily because if you look into the number of varieties that are released in soybeans, where we have the GMOs, and in corn where we have GMOs, or in canola and cotton, we have more varieties released on these crops than those like wheat, for instance, for which there is no GMO. Biotechnology has helped us to bring back lots of older varieties that were not really fit for growing, because maybe they were susceptible to a particular insect. But now we are able to add any insect-resistant gene and bring it back. So my answer is a cautious no. The GE crops will not necessarily accelerate the erosion of genetic diversity within our crop plants. It also gives us a tool to help increase those genetic diversities.

You must recognize that GE is just one part of biotechnology in the wide spectrum of biotechnology tools. For instance, a lot of research has been done in trees and poplars, and scientists in the 90's showed how they can use cryopreservation. In other words, biotechnology offers some really incredible tools to help conserve diversity. In plants like banana, for which we don't have seeds, it is very difficult to maintain the diversity of all those varieties. There's some 20,000 varieties of banana, and all of them are maintained using tissue culture or cryopreservation.

"Farmers are not museum-keepers... You cannot expect them to maintain the diversity."

My final answer is kind of a metaphorical answer to this: you must recognize that farmers are not museum-keepers. In other words, you cannot expect them to maintain the diversity. They are there in the business of farming, and they will always do what is best for their bottom line. So we do have an institutional role in conserving those diversities. We have great gene banks in Colorado, for instance, and Mexico, Norway, and other places around the world where we can maintain diversities.

RE: Is there any advantage to monoculture in agriculture?

CSP: There's really no advantage to monoculture in agriculture; except that the modern industrial agriculture and the demands of consumer uniformity and price, competition, tend to gravitate agriculture towards monoculture. But, we must try to counter that through innovative science, even law. For instance, in Germany, they cannot plant the same variety of tree in a plantation - they have to mix. And as you know very well, there is a relative safety in diversity, and we must aim for that as much as possible.

RE: What about effects of monoculture on soil, water, air and climate?

CSP: In a very strict sense, monoculture means growing of only one variety of one clone. I'm a big history buff when it comes to a lot of these plant diseases and how they've shaped history. I'm sure you know the Irish potato famine, and the coffee rust, and even the corn blight here in the US in '71. They were all caused primarily because of the small genetic base of a crop. Again, I give the example of the Chestnut trees, even polyculture. Great diversity by itself sometimes will not be enough. So, I do believe that monoculture and intensive agriculture that is unbridled, and unregulated, would clearly have a negative impact on the soil. Traditional agriculture, which is very chemical intensive, helps to precipitate many of these problems. I'm not a big expert on that, but a lot of people tend to lump all the new innovations in agriculture together - whether its fertilizers, pesticides, or GMOs. We have to be science-based and look at each fact on a case-by-case basis. You must understand that whether it's the use of fertilizers, or pesticides, it's very critical to help maintain our current food production to help feed the world. We need to be doing a better job, a more responsible job. Whether it's integrated pest management, or use of position agriculture where we take into account the soil fertility levels and use of satellite technologies to make sure we dispense only the right amount of fertilizer, and clearly GMOs with its potential to help reduce the amount of pesticides, and also some of the newer innovations. We have some fascinating research of how we can grow crops that are more efficient in their uptake of nitrogen and phosphorus which, in the future will help reduce our dependence on chemical fertilizers. All of this I do believe, if we bring about in a responsible manner, will help create future agriculture with a lighter ecological footprint, more sustainable, less pressure on soil, water, and all those natural resources.

HW: Another person we are interviewing, Dr. Catherine Badgley, studies organic and small-farm sustainability and states that small farms are not only more economical than large industrial farms, but that they can also provide the essential caloric and nutritional needs for all citizens. What is your opinion on this statement and what has your research shown regarding this topic?

CSP: I'm not familiar with her, but I'm familiar with many of these statements. You need to go with what the peer-reviewed science would tell you, and a lot of these things she says may be correct in certain circumstances. But right at this seat next to me, a few years ago the great Norman Borlaug was sitting. He would have been 100 years old last week - we all celebrated his 100th birthday. What he would've said is, 'Look, organic agriculture is nice, and a lot of things that they claim about sustainability are very important, and and I think we all need to aspire for that, but in the practical terms, there is no such thing as a free lunch.' Agriculture is always going to have an impact on many of the environmental variables that you're talking about. And so if you're in charge of this, how do you allocate your scarce dollars? Or if you're working for the World Bank and it is your responsibility to feed the world - organic agriculture in the sense that it is defined today would not be able to feed the world. That is what Borlaug would say, and I tend to agree with him.

"Agriculture is always going to have an impact on many of the environmental variables."

We worked with a lot of small farmers here and those are very important to us because I work at a historically black university. Many of the black farmers in this area tend to be small, and we encourage them to go organic because it can help bring them to be more ameliorative under some of the more demanding circumstances. So I have nothing against that in principle. But as a policy, if you're involved in formulating food policies, what I say is, you've got to be careful in being very purely evangelical about organic farming because the productivity levels of organic is always lower. It's fine if you want to cater to a small elite crowd who go to Whole Foods, but we deal with a lot of disadvantaged populations around here. We live in a food desert, and if your tomato goes from one dollar a pound to four dollars a pound, people are going to eat less tomatoes. It doesn't matter if it's organic or not organic. So that is far more destructive to us. These low-tech solutions in organic that you talk about - sure many of them have noble aspirations - but in practical realities, published evidence shows that organic food is not necessarily safer or more nutritious or more environmentally friendly. There are certain limited conditions where they may be. And its the same with the GMOs too. Some of the GMOs we introduced were duds and failures. So we need to pick and choose what works and what doesn't work, and if you look at it historically, science and innovation have always been like that. What was hot a couple years ago is not hot anymore. Science and innovation change our perspectives of what is good and what is useful all the time. We can only talk in the current moment.

Even with the Amish - if you google Amish farmers and GMO - the Amish, with all their 18th century technology, are some of the few farmers who grow GMO crops. They have embraced them for some reason. So, I don't think you should say something is low-tech or high-tech - they should look for what works. At the end of the day, we need to be cognizant of the value systems and belief systems. If you have an aversion against chemicals in agriculture, or the use of technology, then I'm not going to argue, because I have my own beliefs over certain things. It has nothing to do with science, right? So we need to be respectful. For someone who wants Kosher food - OK, Kosher has nothing to do with science, but it's all about the belief system. We need to be able to provide and develop a market system that caters to those beliefs. I have some friends who firmly believe in organic, and I have no problems with that. There is a mechanism and a market that caters to that. Or if they are against GMOs, it's no problem.

RE: I was looking earlier today and I saw a website that said that the average size of a farm in India is only one hectare?

CSP: Yeah exactly. About 2 - 2.5 acres.

RE: I was wondering if you could talk a little bit about the different types of biotechnology that can be used in a smaller farm like that, versus the huge farms you see in the US?

CSP: That's a very good question. I travel a lot, even in Africa, and the situation is even worse over there, because not only the farm sizes are small, but the farmers are much more resource-poor. So things are more simple over there. Any intervention that has a very high cost, that requires a lot of expensive input, is going to be burdensome to those farmers. And also, in economics we have a certain scale of operation. Farm sizes that are very small do not lend themselves to mechanization, so our Indian farms do not have tractors, all the things that you see here in Michigan for instance where they have 2,000 acres of corn and they can bring in all this mechanization. So under small farm conditions and resource-poor conditions, we need to be very cognizant of that. I do believe that biotechnology is far more scale-neutral compared to other technologies such as mechanization. A good example is in India. Cotton farmers: we have over 6 million cotton farmers in India who grow Bt-cotton that has been genetically engineered for insect resistance, and the acceptance rate of this Bt-cotton has been 98%. In other words, practically all the cotton farmers in India, even those who have just half an acre farm, which is so small - smaller than my backyard - and yet, they are willingly spending about 20 to 30 dollars per acre more on buying this Bt cotton seed because those farmers recognize the value that they get in spending extra, because the economists have worked out that they reap anywhere between 100 to 150 dollars in returns for that extra 20 dollars that they spend. So having said that, I do believe that the private sector is probably not going to cater to the needs of small farmers. We have far more private sector activities for that. Private philanthropy, such as the Bill Gates foundation, have a greater role to play in catering to the needs of small farmers. This doesn't exclude the private sector, but it's just, we need to be aware of the realities. Unfortunately when it comes to biotechnology, the private sector is more dominant. Monsanto spends 3 million dollars a day on research on GMOs for just four crops: corn, cotton, soybean, and canola. So you can imagine just the budget of one company's R&D, is more than the combined agriculture budget of say 50 countries in Africa. So it's clearly very lopsided.

RE: Have you heard about how the type of banana that is most commercially produced in the United States is going to be wiped out? How do you think problems like that can be avoided in the future, and do you think that's going to be a major problem?

CSP: That's a very important question. Gros Michel I believe, is the variety that is used all over the United States, it's a type of Cavendish banana. Here is an instructive example where technology can help. If banana is lost in the United States, it's not a big deal because we will probably switch to other fruits. But in Uganda, and other places, they eat bananas, plantains, as staple foods. So if the plantain is wiped out, it really affects the livelihood and the nutrition of millions of people over there. Researches in Belgium and France and a couple other places have worked with Ugandan scientists to develop a kind of banana that is resistant to that disease. So, this again goes back to my underlying point that you're always pretty vulnerable to the wiping-out of a food base. Most people do not realize that 95% of our food calories come from five crops. Many crops are artificially propagated - potato, cassava, sweet potato, and banana. Not just the GMOs, but also tissue culture, cell culture, and a lot of newer technologies that are coming up called gene editing, where we essentially tweak the genes (you are a molecular biologist–you know some of the things I am talking about, like CRISPR), those techniques where we don't introduce any foreign genes, but we could probably just alter genetic information of the existing DNA and develop less toxic cassava, or more nutritious sweet potato, or perhaps a banana that is resistant to the fungal disease. It's even more recent that we need to have an open mind for some of the new technologies.

RE: So in other words, dependence on things like single types of crops, and the vulnerability to wipe out crops, is a problem, but it's not *caused* by biotechnology or GMOs, but biotechnology and GMOs are probably the solution?

CSP: Exactly. And it's not the only solution. Having a greater diversity of sources would help. And clearly, today we have GMOs. Ten years from now, with all the advancement that's going on in genomics, we'll have a much greater sophisticated tools at our disposal that will probably help, and greater levels of insurance of stability for production.

RE: Thank you so much for speaking with us, Dr. Prakash.

HW: We've learned through our interviews that even early agricultural societies recognized the importance of genetic diversity, but mass-production of crops through monoculture enabled us to grow larger in population. Today, these practices have been pushed so far that entire states in the US are dedicated mostly to a single crop. The use of pesticides and genetically modified organisms has scared people into buying organic produce. Although there is a market for organic produce, it is still very small and isn't necessarily able to sustain our current lifestyle. Biotechnologies have become necessary to stay one step ahead of a rapidly evolving nature. They have enabled us to introduce genes into plants without intensive breeding and could also help us preserve diversity. At the same time, legislation should be put into place in order to preserve the environment, human rights and people's beliefs. When used in a responsible way, biotechnology can raise the economic viability of farms and contribute to the well being of agriculture-based societies. By it's very nature, biotechnology and industrialized agriculture are not necessarily harmful, but they must be used with environmental and humanistic impacts in mind. Research has taught us what agricultural practices work best, but economics will determine what methods will ultimately be put to use. We'll have to make modifications along the way as our climate and culture change.

Thank you for joining us tonight. See you next week. Good night.