Other Approaches to Adaptation

Panel Discussion and Q&A

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Jeffrey Schoenau: As a scientist and a farmer I was impressed with the information and the insight provided by the three speakers. One of the things that I found interesting on crop adaptation to climate change relates to semi-arid systems unable to support cropping in the future. That's where I farm, in the Palliser Triangle, and I guess this thought has come up before. It certainly came up in the 1930s and came up in the '80s again. But, interestingly, out in the farms you don't hear a lot of this anymore and part of the reason is because of reduced tillage and improvements in water conservation and soil conservation. Compared to 30 years ago, things are a lot better. Although that's a success story here in the prairies, I believe that there is opportunity for further water conservation in anticipation of drier conditions down the road. So, I put that forward as a challenge, that there is opportunity for further improvement.

The other thing that made me think was the talk about adaptation. You know, plants are tough. Some do well under adverse conditions. Some weeds, for example. One that I battle every year, kochia, is able to develop resistance to a wide variety of herbicides. It likes it hot. It likes it cold. It's always there. What makes it tough? Can we capitalize on some of the genetics of those kinds of plants and bring those characteristics into our cropping systems?

Talking of cropping systems, Don made me feel good because there is lots of potential for improvement. With winter crops, we can take advantage of the early spring moisture from snow melt and avoid the terminal July drought that tends to get us in the southern prairies. Early seeding of spring crops, timely planting, was brought up by a couple of speakers. If you farm 1,600 acres like I do that's a great thing, but some farms now are 16,000 acres such that timeliness can be a real challenge. That's something that's being addressed from the equipment side, but greater efficiency oftentimes means a bigger operation, for better or for worse.

The modeling was interesting *vis-à-vis* spring wheat moving north, and, as we look at changes in cropping patterns, I believe that new crops and new cropping systems will be adopted to fill niches left behind. Jeff brought up double cropping, and maybe that's something that we should start to think about here in the southern prairies. Winter peas that are harvested early in July could be followed by a short-season cereal harvested in October. This may seem farfetched and certainly it would take water to do it. Farmers would spend a lot more time in the field and would have to make better use of precipitation during the growing season, and water from snowmelt, to capture that late-season photosynthetic potential. Also important, covered by Jeff, are cropping systems, rotations, and options like planting time and row spacing. We need that kind of agronomy and extension of that information to growers so that they have a sound basis for making their decisions.

Dr. Lal built a strong case for the importance of soil and I agree with that. Organic matter does so many wonderful things for the soil itself and, of course, is an important reservoir of, and sink for, carbon. He pointed out the importance of efficiency, which is key in economics. It's key in mitigating and adapting to climate change. I tell my students in my soil fertility and fertilizer class, with regard to fertilizer nutrients: use them, don't lose them. Replace what you remove; that's very important. And when it comes to recycling efficiency, some of the research that I'm involved with gets to the whole biofuel question, *i.e.* recycling those nutrients and that carbon in byproducts like glycerol, like stillage, and manure from cattle that are fed distillers grains. Those are ways to get those nutrients and carbon back into the system. A lot of fertilizer will be needed to achieve the yields that we will need down the road and we must find ways to be more efficient. One of the ways is putting back in what you take out by adding to the land products that might be considered waste, but actually when managed properly are an important resource.

Bedard-Haughn: Dr. Pennock would you like to respond?

Dan Pennock: I echo what Jeffrey said: it's heartening to realize the range of options open to us to deal with climate change. Sometimes it's presented as almost a hopeless case, but we heard about genetic improvement, variety improvement, cropping practices and soil changes. All the adaptations that we've talked about will be evaluated for yield or biomass response but also increasingly in terms of associated greenhouse-gas costs. Nations now have to do accounting for their greenhouse-gas balances and, increasingly, sectors and individual farmers will do so. The northward expansion of spring wheat is a good example, to which Don alluded. If you move out of the grassland soils in the prairies you are moving into an area that is forested, and there is a tremendous carbon loss associated with deforestation. Secondly you are moving on to soils that are nitrogen-poor relative to grassland soils, hence you will need significant inputs of nitrogen each and every year which are not as necessary in the grassland system. And the IPCC factor for nitrous oxide emissions from N fertilizer is 1.25%. Then add losses of N_2O, which, as Rattan pointed out, has a global warming factor 296 times that of CO_2; it's easy to generate significant N_2O emissions from relatively infertile soils. So although northward expansion may involve yield increases, greenhouse-gas costs will be associated with it.

As climate change becomes more apparent, I think that all activities in our economy—certainly anything to do with agriculture—will be more and more evaluated in that light and any adaptations will be viewed accordingly, including adaptation and mitigation, such as adoption of carbon-sequestration practices. Adaptation will be the aggregate of thousands or hundreds of thousands of individual farmer choices. Jeff talked about this in terms of extension's role, but it's also the aggregate of individual farmer choices as influenced by policy and economics. Adoption of new seeding rates or cropping varieties will occur based on information presented to extension within the context of greenhouse-gas costs and associated economic potentials. And Linda Mearns talked about it yesterday. It's complex. For example, in Canada recently, the federal government announced that there will be a carbon benefit for adoption of no-till beginning from 2006. The many farmers in Saskatchewan who adopted it before 2006 will get no credit. The national balance benefits from it and Raymond talked about that yesterday; the decline in summer fallow contributes substantially to soil switching from a source to a sink. That no credit will be given from before 2006 may cause some perverse responses. Farmers may put things into a summer fallow to be able to get the benefit starting in 2006 and in future cropping years. Many farmers are very unhappy with that and Soil Conservation Canada has been active working against it. It's an example of a policy decision that will have an impact on the adoption of the mitigation measure and it may be a perverse impact compared to what they hoped to achieve.

The final point I would make deals with the complex response that several have talked about, and this morning we heard from one of the speakers that a second Green Revolution is needed. When you consider the need to feed the 9.5 billion people who will be on the planet by 2050 and the undeniable growth in modern biomass sources for energy, much more plant production will be needed. We all know that. Although the first Green Revolution, of course, was a tremendous success story, in some regions tremendous costs were associated with it. The point made effectively by Dr. Lal was that by considering the cropping system as a whole—the contributions of soil science, cropping patterns, crop development—we can avoid the deleterious impacts of the first Green Revolution as we advance the necessary Green Revolution of the future.

Angela Bedard-Haughn: Dr. Smythe?

Stuart Smythe: I don't think I can fill 5 minutes of discussion on this as I'm not a soil scientist. I did have the opportunity last week to listen to Derek Byerlee give a presentation on the World Bank's 2008 agriculture report, and I have a couple of observations to offer to the speakers for their insights. Forty years ago annual crop yields increased annually by about 3 to 4%. Those have declined down to on an average of about 1% for cereals. Byerlee also stated that fertilizer production will peak in 2017. Factoring in declining yields and fertilizing peaking in 7 or 8 years, if we look forward to a 2020 scenario, what will be the highest priorities for agricultural research and where will we go for funding?

Don Smith: Clearly, issues with nutrients and nutrient recycling need to be addressed related to fertilizers. We need to collect whatever is left from biofuel manufacture for nutrient recycling. In my view, phosphorus is the most important. There are alternatives for nitrogen. There's still a lot of potassium in the world, so phosphorus is going to be a big issue. Water is going to be a big issue. Energy will be an issue. Those would be the ones I'd pick. And let's not forget climate change.

Jeffrey White: You asked a good question about where we go to get the funding. More and more, this is a serious problem and in my own work I'm beginning to ask myself, "Who are my real stakeholders?" We keep talking about farmers, but I think maybe my stakeholders are industry representatives. In ARS[1] climate-change research, our big products have been for policymakers, such as IPCC-type impact reports, but we need to get to the growers' associations. Cotton Inc., which isn't for a food crop, is a good example. It has been responsive to our first contact. They realize that cotton farmers aren't going to make billions of dollars from carbon credits. They should be thinking more about what is the impact of climate change. There are opportunities there.

On the nitrogen issue, a big question is, "How much nitrogen usage has been wasteful just because nitrogen was undervalued?" As fossil-fuel costs go up or other things kick in to raise nitrogen cost, we will see farmers looking to more-efficient ways to use nitrogen, or they will change their crop mixes. In the United States, some farmers may get out of corn and go back to wheat if nitrogen prices dictate it. On the other hand, new nitrogen formulations are coming along, which may cost more but will make nitrogen use more efficient.

Rattan Lal: With rain-fed agriculture, where yields are declining or stagnant, one ton per hectare is a good yield in South Asia. In Sub-Saharan Africa, where rain-fed agriculture is normal, less than one ton per hectare may be expected on a national basis. Yields can very easily be 3 tons or 4 tons. Experimental yields are 5 tons, 6 tons. Getting from 1 ton to 3 tons in rain-fed agriculture, requires good soil and water. In sub-Saharan Africa, 5% of the land is irrigated. So, expansion of irrigation is needed, not only just with flood irrigation. I hope that we do not just waste water by that system, as is the case in South Asia and elsewhere. Drip sub-irrigation is desirable if that can be done, fertigation and condensation irrigation. We transport water as a liquid; perhaps it might be easier to

[1]Agricultural Research Service of the United States Department of Agriculture.

transport it as a vapor and condense it directly on plant roots. That certainly is possible in terms of innovative technology. Once the water becomes available in sufficient quantity, nutrients would be of importance. As far as irrigated agriculture is concerned let's take the case of the Indo-Gangetic basin, with which I am familiar. Water tables are declining rapidly. Why are they declining? We are flooding rice in an arid environment. What do you expect? What happens in a sandy soil? So, the water tables are declining. Can we find a viable alternative? Someone talked about a cotton/wheat or maize/wheat system, neither of which is as economic as rice/wheat. Rice is a staple for the region. Can we find better ways to grow rice? Can biotechnology produce rice which, rather than needing flooding, can yield well under aerobic conditions? These are the kinds of interdisciplinary things we need to talk about. The June issue of the *National Geographic* magazine has an article on Punjab, and one thing you may notice is a large truckload of straw being taken to the markets. I see that whenever I go there. The wheat-straw price is 70% of that of grains. Tell farmers to add that back to the land to increase soil organic matter content and they will think you've gone crazy.

Regarding funding support, we must compensate these farmers for ecosystem sources that they provide to the world community. No handouts. No emergency knee-jerk approach of giving emergency aid to any community. These create corruption and kill morale. Let's pay them for ecosystem sources, for example for carbon sequestration to mitigate climate change. If farmers can be paid for carbon sequestration in soil which has many ancillary benefits why should he sell straw at the market? We can pay for ecosystem-source effects on water quality. We can pay for ecosystem-source effects on biodiversity. If we can develop a system that provides another income stream to farmers for doing the things that they are doing for society as a whole, so they are not given handouts, that is eventually the way to fund this kind of research on a long-term basis. In the short term, obviously we need donor support and we need our directors of experiment stations and deans and others to go to the bureaucrats in Washington to relate what research support we need from USDA. However, eventually it must be a self-driven system.

Carbon is being traded on the Chicago Climate Exchange at $2.50 per ton, which is $8 per ton of CO_2. You are talking about half a ton per hectare of carbon under the best-case scenario in Ohio and Midwestern United States. That roughly comes to $2 per hectare per year. What farmer is going to get excited about having $2 per hectare per year? If you take a kilogram of humus and analyze it for nitrogen, phosphorus, potassium, zinc and the water it can hold, it is worth about 40 cents at current prices. That's $400 a ton. Yet, we are paying farmer $8 a ton. That's undervaluing a very precious commodity, and undervaluing leads to abuse and misuse.

Bedard-Haughn: Questions from the audience?

Dorothy Murrell (University of Saskatchewan): Dr. Lal, you showed a picture of corn grown with continuous removal of residue vs. continuous return of residue, showing a night-and-day difference after a number of years. What does that say for biomass removal for fuel production? Is it wise to remove it, whether it's wheat straw or corn stover?

Lal: I wrote an article in 2007 titled *There Is No Such Thing as a Free Biofuel from Crop Residues*[1]. I do not believe in crop-residue removal. A couple of articles in *Science* talked about a billion ton biomass dream, of which 400 million tons would be corn residue from the Midwest corn belt. I think there would be a heavy price to pay if that were the case. Crop residue removal for biofuel production is not a solution. Not at all. Neither is converting tropical rain forests such as in Malaysia into oil-palm plantations for biodiesel. Considering the total ecosystem carbon pool, when you deforest you release 400 to 500 ton of carbon per hectare. An article by a colleague at Princeton estimated that it will take 132 years just to pay back the debt, not to offset it.

Where does the biofuel part fit here, in competition for land for food production? I mentioned yield stagnancy in rain-fed agriculture. We are going to need an additional 400 to 500 million hectares to meet the food demand by 2050. To meet a requirement of mixing 10% ethanol with gasoline will require about 800 million hectares of land for energy plantations. We don't have it. My advice to policymakers is to improve energy efficiency, and conserve energy by switching off the lights, adjusting the thermostat, carpooling, whatever. We can save anywhere between 25 and 40%. Sequestering carbon back into forests and soil as another part.

The long-term solution is to find a non-carbon fuel. The carbon age, like the stone age, will soon be over. During the carbon era, 1750 to 2100, we messed up the carbon cycle. We've got to restore that cycle. So, we've got to find a non-carbon fuel source, whatever that might be, maybe solar, maybe wind, maybe nuclear, maybe hydrogen, as long as the hydrogen is from water and not from fossil fuel or biomass.

So, to answer your question, many people talk about algal farms, perhaps cyanobacteria, and I think there may be few niches for that. It's possible to use large city grey water from Mexico or Delhi or Calcutta or Rio de Janeiro where you have lots of nutrients in water. It's possible to grow some algal biomass. It's possible to grow perhaps some halophytes with saline or brackish water irrigation to produce biomass, but to meet a 10% requirement from biofuel requires different thinking. Soil scientists, agronomists and policymakers need to sit down together and talk rather than just make a rhetoric statement yes we can take corn residue and make cellulosic ethanol. It's just not feasible. If you do a complete life-cycle analysis—and that is what is required—you will see that biofuels cannot meet the carbon requirement. The long-term solution is not biofuels.

George Wagner (University of Kentucky): Dr. Lal, biochar seems to be the latest popular magic bullet, and the notion is you can put it back into the soil without any consequences. I'd like your opinion of what those consequences might be.

Lal: Wim Sombroek was the secretary general of the International Union of Soil Science for many years and director of the Land and Water Division of the UN Food and Agriculture Organization, and in his young days he served as a soil surveyor in the Amazon and found that amongst the red soils, mostly oxysols, are patches of black soils very high

[1]http://wwwtest.soils.org/about-society/presidents-message/archive/2.

in organic matter content. The Indian tribes were harvesting biomass and burning it and returning the ash and charcoal back on the soil, which was very productive. Rather than being sandy, the organic matter was increased along with nutrient retention and water retention. I saw the soil profile of that in a soil museum in Holland recently and those soils look excellent, beautiful, after thousands and thousands of years. Wim called them Indian black soils. Now, since that article was published, there has been a lot of movement that perhaps we need to do the same thing. A few experiments have been done over the last 3 to 4 years where we find that applying biochar generated through the pyrolysis process—burning biomass at 400 and 500°—we can convert some of that biomass into syngas or into liquid fuels and 30% of it could be converted to charcoal, which is an inert material. It has a high surface area and a high char density. Applying it to soil at about 50 tons per hectare increases organic matter content, and improves soil fertility. It's a great thing to do. I reviewed a grant proposal to put biochar into sand dunes of Saudi Arabia. Where are you going to grow 200 tons of biomass in Saudi Arabia in order to apply 50 tons per hectare? They are rich enough; they can acquire a glacier for water from somewhere. The UN is adopting a resolution to mitigate climate change with biochar in the Sahel. Again, where is the biomass coming from to produce 50 tons per hectare of charcoal? If the capacity existed to grow 200 tons per hectare of biomass, we would have no problem in the Sahel. The Amazon Indian tribes had all that forest around them and were able to do it. Now, that is not to say there are no niches. If we were close to a sawmill, it is definitely possible to take sawdust and convert that into biochar and use it. If you are next to a dairy farm in Ohio with 400 cows, take that manure and burn it to produce energy and convert it to biochar. You've got some niches, yet I have a problem. Two of my graduate students need a ton of biochar to put on small plots, 10×10 meters. I can't find it anywhere. If we were in India I'd find a rice mill where they burn the rice husks for conversion to biochar. So there may be a few niches, but to imagine that you are going to put 50 tons per hectare of biochar onto 2 billion hectare of land to sequester carbon in soil, think again.

Adekunbi Adeleke (University of Saskatoon): Biofuel production is very important. We can produce more yield to provide food for those that need it. And we can leave some crop residue on the soil and at the same time use some for biofuel production. My point is, everybody is needed. We need engineers, flex-fuel cars that use fuel more efficiently and we need plant breeders to produce plants that can use of nitrogen and water more efficiently. Soil scientists, agronomists, plant breeders: we all have to work hand in hand and there is no way we can do this without biofuels.

Lal: She's right. We need all them working together. She said it very well.

Malcolm Devine (Performance Plants): Jeff, you are the one who needs to answer this, because it's about maps with colored shady bits on them. It's a subject I've heard a lot about in the last 36 hours, so I consider myself a *quasi*-expert now. You made a comment that struck me and then you moved on from it very quickly. It was in relation to the spring wheat in North America. You had the band of spring wheat straddling the 49th parallel—a little bit below and most of it above—and with the typical climate-model temperature change, you said almost as a throw away comment, "As long as the soil can support it." I think about this a lot when I look at these colored maps and the red that's shifting up or the yellow that's shifting left or whatever it is. Someone is doing the climate stuff and the growing degree days, and whatever else that goes into all of this, and so the spring wheat will be better adapted 100 or 200 miles further north. But, is someone also looking at the ground level and below ground so that they don't produce a situation where the top half of the band now is overlying what is currently forest soil, relatively low pH, about 25 cm thick and there's 3 miles of solid rock underneath it, and you ain't going to grow a crop on it. Sometimes we see these things and think, "Well that looks good but, wait a minute, that's over the ocean now or that's in the Rocky Mountains." Help me bring these things together.

White: Certainly there are many good soil maps. But when I was at CIMMYT[3] doing these kinds of analyses, the big problem I found with maps was that they describe soils in terms of frequencies and similar things. The concept was that 60% of a soil in an area might be suitable, 30% less so and the rest just not suitable at all. Some good initiatives are trying to solve the soil-data issue, so that we have essentially the equivalent of the climate surface, but a soil surface, for the world. Pedro Sanchez is involved in this digital soil mapping of the world and I hope that moves ahead. In my analyses for winter-sown spring wheat in the south, I need to overlay that on land subject to irrigation. I would not want to show the map I put up to the governor of Arizona because he would say, "Oh great, a quarter of Arizona is going to be suitable for spring wheat soon," because the water is just not there. In fact, all scenarios show that the water is disappearing, but certainly the next generation of analyses have to bring a lot more rigor in. And then there are questions about seasonality. Monthly data, such as the coldest month, don't capture what's going on either. I see that in Arizona. We have some higher elevation sites that are good spring-wheat environments, yet they actually sow in March. If I used a growing-degree approach I could capture that difference, but if I just use coolest-month data they fall off the classification system.

Pennock: Tim Sutton from Australia made effective use of soil maps as well as real climate sequences. That's an example of using both good soil-resource information as well as realistic climate information to make sure that the plant product meets needs. But I agree that we don't see enough of that. Soil-resource information is out there. Someone at the CSIRO[4] effectively mobilized their soils people and their climate people and the plant people to ensure they were looking at all aspects of that. I don't think we do it very well in Canada. I can't speak to Arizona, but in Canada we simply don't use our existing

[3]International Maize and Wheat Improvement Center, Mexico.
[4]Commonwealth Scientific and Research Organization, Australia.

information very well. The soil mapping in Saskatchewan cost millions of dollars and is largely unused for this kind of issue. I don't know why.

Claire Sullivan (University of Saskatchewan): I agree with Dr. Lal that sustainable soil management will create healthy communities, but I struggle with the fact that climate change is coming and world population is growing and our focus is largely on yields, relying heavily on fertilizers and other inputs to the soil. Dr. Lal talked about replacing whatever we take out. Organic would be the best way to do it, but he said that it would be a crime to tell farmers not to use inorganic fertilizers. But where do you fight greenhouse-gas emissions? Fertilizer production consumes energy and produces waste. Then you are saying that new varieties of crops will need fertilizer, so I am struggling with that.

Smith: You are right. Inputs are important in terms of achieving yield potential, but there is the issue of how much of any resource you can put in. One important resource is energy, and if you put in more nitrogen fertilizer, for instance, you are very tied to energy costs and if energy costs are rising you get into a bit of conundrum. Conservation is an important issue. Dr. Lal mentioned that. But my fear is that any reductions made here—and we should make them no matter what—may be offset by expansions in developing economies with no gain in the long run. We need to encourage conservation everywhere of course, but the problem may not go away just because of that. You can argue that if you produce biofuels you may be driving up the price of food, but if you don't provide some kind of alternative sustainable energy source, the price of food will rise anyway.

Lal: From 1900 to 2000, we did so many things on such a scale that if we were to repeat it between 2000 and 2100, we would need several more planets. When we talk about another 3.5 billion more people, what kind of lifestyle will those people have? We have to begin to think about how to decrease demands on natural resources. We seldom talk about that. We always say, "We are going to have 10 billion people. How can we double food production? How can we double the energy availability? How can we improve the efficiency?" But we don't talk about how we can decrease demands. It will not be possible for 10 billion people to live with the same standard of living as in North America and Western Europe. Somewhere along the line, we have to think about how to cut down on resource exploitation.

Food preferences: is it possible to sustain meat-based diets as currently, and is it even healthy to do that? Is it possible for the United States to continue *per-capita* energy consumption at the current rate? China's rate is a fifth of that and India's is a twentieth. Can China and India come to the same level of *per-capita* energy consumption as the United States? Does progress mean continuing to improve standards of living? We also need to think in terms of sustainable use of natural resources, not just in terms of meeting increasing demands. Where can we cut down the demand? Where can we reduce? Where can we recycle? Where we can do without? These are important questions for students to think about.