Workshop Summary

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Three breakout sessions were held at NABC 21, comprising a total of five workshops, at which the major issues raised during the plenary-session modules were enumerated and discussed. This is a synthesis of key points that emerged.

Module 1—Climate Change Overview and Projections

- Stakeholder engagement and education will be critical. (Stakeholders include policymakers, agricultural scientists, climate scientists, ecosystem-service providers, farmers, biotechnology industry personnel, economists and consumers.) All available means of communication regarding climate change effects on agriculture and food production need to be employed: extension agents, the Internet, "traditional" media and the scientific literature. In particular, scientists must reach out to policymakers.
- The need for such engagement and education is not limited to the subtleties of climate change, but includes the relatively more mundane aspects of production agriculture.
- Most politicians have a non-scientific background, making it critical that knowledge be communicated in ways that they understand.
- Most policymakers lack the knowledge-base to weigh the issues and the options.
- A complicating factor is the uncertainty inherent in available computer-simulation models. Improvements in these models must continue, with the objective of producing quantitative data.

— On the other hand, it was suggested that the lack of precision is sometimes overstated, and more emphasis is needed on development of protocols for managing uncertainty. Some participants felt that there is too much emphasis on climate models and too little on decision-making protocols. Such protocols, as used in medicine, may have utility, underscoring the need for interdisciplinary effort.

— Unequivocal data will help to address points raised by skeptical activists.

- Demand-side pull may be an important driver, including voluntary carbon cap-and-trade markets, green products and organic foods.
- With climate change, the frequency of extreme weather events will increase, with which risk-profiles will also change. The insurance industry will require accurate evaluations in order to price risk.
- Population increase must be factored into predictions of the results of climate change. Also important are improving living standards in China, India and elsewhere leading to dietary changes, in particular increased meat consumption.
- Emphasis is needed on optimizing efficiency of use of all inputs involved in production of food, fiber and biofuels.

  — Only with accurate life-cycle analyses of all input and output components can sustainability be achieved.

Module 2—Genetic Approaches to Crop Adaptation

- The roles and contributions of breeders and molecular biologists need to be examined and better integrated.
- Concern was expressed over the lack of availability of plant breeders. For example, not a single university in the UK provides training in traditional plant breeding. Non-molecular skills are being lost in other disciplines. (An encouraging note: Pioneer and Monsanto are funding university courses for training plant breeders.)
- The need for interdisciplinary teams begs the questions of how they should be created, and who will be the partners. Not only should industry, academia and government be involved, but input should be sought from farmers and consumers.

  — If farmers are paid for ecosystem services, they would be more amenable to adoption of appropriate new technologies.

  — Optimization of these various contributions would provide new justification for funding.
- Dynamic systems approaches are needed in making genetic improvements for resistance or avoidance of biotic and abiotic stresses that will become more severe with climate change.
- Major research efforts are needed to improve efficiency of water use and of photo-

synthesis; these important factors are linked.

- Means and funding are needed to analyze and identify useful traits in thousands of accessions held in plant-germplasm banks. Technology is available to characterize them genetically, but gaining understanding of their phenology will be problematic.

Module 3—Other approaches to adaptation

- Depletion of carbon (*i.e.* organic matter) from soils—and concomitant loss of fertility—is an issue of major importance, particularly in view of the fact that soil has huge potential as a sink and reservoir for carbon. Tillage and other farm-management practices need to be modified so that organic matter is replenished and fertility—including water-holding capacity and nutrient retention—thus maintained or improved.
  - — Removal of stover and straw as a feedstock for cellulosic ethanol production was questioned. If more nutrients are removed than put back, fertility will be lost.
  - — On the other hand, biofuel production will continue to increase and must be integrated sustainably.
- Methods of soil-carbon monitoring need to be improved, and quantification of nitrous-oxide emissions made more precise. These factors are sensitive to even small fluctuations in temperature and soil moisture and will be affected by climate change.
- Soil microbiology must be part of the discussion.
- Moisture relations will be increasingly important as pressure on water resources increase and warming trends increase evapotranspiration. There is potential to breed for improved water-use efficiency in crops as well as for moisture-stress resistance and avoidance.
  - — It will be important to understand and make allowances for how new policies related to climate change will affect other countries. Multinational engagement will be necessary. Judicious application of scientific knowledge is highly desirable.
- Ecosystem services and their sustenance are not adequately integrated into currently available computer-simulation models.
- More rigor is needed in predictive models as the basis for formulating strategic plans to justify new sources of funding.

Module 4—Ethics, Policy, Carbon Credits

- Profit taking and ethics are not necessarily mutually exclusive; it depends on the underlying motivation.

- Applying ethics to practical situations can be difficult for non-ethicists. Providing opinion must be viewed differently from weighing ethical considerations. Ethics are derived from principles and not from social mores.
- Unequal distribution of wealth is not necessarily unethical. Critical considerations are how we treat others, future generations, and plants and animals.
  - Good examples are the Enviropig, produced for profit, which benefits the environment, and genetically engineered crops that will adjust to climate change.
- Moral and ethical issues are now represented by the media, the motivations of which may be questionable. Scientists need to take a stronger role and work with journalists.
  - On the other hand, many scientists are poorly aware of ethical issues[1]. It was suggested that scientists should have ready access to ethics inputs, to guide their research. Similarly, teaching should incorporate ethical considerations.
- The science of mitigation of climate change is now being elucidated, but there has been little progress on the policy side.
  - Since the scientific basis for policymaking has considerable uncertainty, it is recommended that policies be adaptable to accommodate improved data.
  - To transfer science into policy will require engagement of politicians to ensure that their decisions are based on sound scientific data.
  - Scientists and students should be taught how to give advice, not how to make policy.
- Cap and trade is the policy most embraced, but there is much to be said for a carbon tax.
  - Cap and trade is being wrongly labeled as a tax.
  - Incentives will achieve more than a tax.
  - Sound scientific data must underpin the cases made for cap and trade and other policies under consideration.
- Interdisciplinary collaboration will be essential, requiring natural and social scientists of various kinds to work together.

[1]For several years, NABC sponsored an annual Bioethics Institute to provide training for university faculty involved in genetic engineering. A similar institute may have utility, with emphasis on research to mitigate the effects of climate change.