APEC Climate Symposium 2016
Proceedings

Piura, Peru

September 16-18, 2016

This document summarizes the presentations and discussions from the APEC Climate Symposium (APCS) 2016, held in Piura, the Republic of Peru at the Casa-Andina Private Collection Hotel on September 16-18, 2016

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APCC would like to extend its sincerest thanks to its financiers, invited speakers, and all participants for their contributions to the event's success.

Acronyms and Abbreviations

AgMIP	Agricultural Model Intercomparison and Improvement Project
APCC	APEC Climate Center
APEC	Asia-Pacific Economic Cooperation
CCAFS	CGIAR Research Program for Climate Change, Agriculture and Food Security
CGIAR*	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIP	International Potato Center
CSA	Climate-smart agriculture
ENFEN	Multisectoral Committee of the National Study of El Nino, Peru
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
GFCS	Global Framework for Climate Services
GGCM	Global gridded crop model
GISS	Goddard Institute for Space Studies
IFPRI	International Food Policy Research Institute
IGP	Geophysical Institute of Peru
IMARPE	Ocean Institute of Peru
NASA	National Aeronautics and Space Administration
RIMES	Regional Integrated Multi-Hazard Early Warning System
SENAMHI	National Meteorology and Hydrology Service of Peru
UNEP	United Nations Environmental Programme
UNESCAP	United Nations Economic and Social Commission for Asia
UNFCCC	the United Nations Framework Convention on Climate Change

* CGIAR formerly stood for the Consultative Group for International Agricultural Research, but is now no longer an acronym

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Overview

1. The APEC Climate Symposium 2016 was conducted from September 16-18, 2016 at the Casa-Andina Private Collection Hotel in Piura, Peru. The meetings of the APCC Science Advisory Committee and the Working Group were also held in conjunction with the event.

2. The event was attended by more than 80 participants from 21 economies – Australia, Canada, Chile, China, Chinese Taipei, Columbia, Germany, India, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, the Philippines, Peru, Russia, Thailand, United States, and Vietnam. The participants included keynote and invited speakers, representatives from National Meteorological and Hydrological Services, government officials, media, non-governmental agencies, and academia. Experts from a diverse range of backgrounds, including climatology, agriculture and fisheries, were invited to speak about and discuss the impacts of climate change on and the use of climate information for food security in agriculture and fishery planning and management. A complete list of participants can be found in Annex I.

Executive Summary

3. The APEC Climate Symposium, which focused on "Smart Climate Information and Accountable Action: Achieving Sustainable Food Security in a Changing World," addressed numerous aspects of food security, from the perspectives of agriculture and fisheries.

   In the opening and keynote sessions, speakers highlighted the importance of making use of technology and data to bridge knowledge limitations and move towards an action agenda in tackling one of the most central concerns of the 21st century: food security. The critical role of two-way science-policy dialogue, as well as more integrative and participatory approaches, were stressed as important factors in making sustainable progress.

   The first session, *Utilizing Climate Science in Agriculture: Impacts of Extreme Weather and Climate Events on Agriculture*, focused on the shorter term impacts of extreme weather events and climactic variability on agriculture, where climate change impacts may be most prominent. Speakers explored how improving forecasts, in addition to technologies like remote sensing and crop models, can help us understand the threat from weather extremes today and the way that extremes change with the global climate. They stressed that the availability, access, utilization, and stability of the food supply in addition to nutrition are all important for food security and must be factored into risk management. Speakers also underlined the usefulness of decision support systems in assisting farmers to build robust climate-smart strategies, which often require persistence across interannual extremes.

   The second session, *Employing Climate Science for Long-Term Agricultural Planning*, explored the long-term implications of climate change and current approaches in

building sustainable and resilient systems. Speakers investigated the appropriate use of climate information tools, seasonal climate forecasts, climate-smart agriculture, and risk management. A balanced perspective was used in discussing various tools and methods available, with traditional methods and knowledge highlighted complimenting modern facilities like genebanks, as key components in a comprehensive approach. Furthermore, given the level of uncertainty of the future, the importance of providing a diverse portfolio of options to farmers was stressed, when using any number of tools and such as models, forecasts, and decision-support systems.

In compliment to the discussion on the agricultural aspects of food security, fisheries and aquaculture was explored in the third session, *Long-term Solutions for Threatened Fisheries Caused by Climate Change*. While there are many parallels between the two systems, experts stressed that sustainable production requires healthy ecosystems with robust biodiversity. Sustainable production is even more strongly linked to environmental management, which in turn may require substantial changes in the consumer habits as well as the regulating institutions. The experts felt that, while there are many challenges ahead, particularly from a governance perspective, there is also great promise in carefully expanding aquaculture and using innovative technologies.

To close the event, a final panel session was held. Experts discussed the relevance and applicability of the topics to their research or role in government or academia, grounding the discussions in the practical context of everyday work. The panelists linked the key outcomes above, to their personal experiences in mediating the science-policy interface, and fielded questions on how to proceed with the symposium outcomes.

Opening Ceremony

4. The APEC Climate Symposium 2016 opened on Friday, September 16, 2016. The Opening Ceremony began at 9:00 am with Ms. Sangwon Moon, the head of the External Affairs Department at the APEC Climate Center (APCC), opening the ceremony and welcoming everyone to the event. She introduced the guests sitting on the stage. Ms. Moon introduced Dr. Hong-Sang Jung, the Executive Director of APCC. Dr. Jung gave his Opening Remarks and spoke about the importance of this event. He concluded his speech by welcoming everyone to the symposium. Engineer Amelia Ysabel Díaz Pablo, Executive President of the National Meteorology and Hydrology Service of Peru (SENAMHI), followed with Opening Remarks as the symposium's co-host. Eng. Díaz Pablo extended a warm welcome to all the participants, before explaining the significance of recent variability in hydrometeorological events in Peru to the economy and vulnerable populations. She explained how food security and climate change are two main challenges we must face, expounding the importance of a multidisciplinary approach like APCS and explaining the relevance of SENAMHI. She explained how APCS is a great opportunity to learn from each other and expressed optimism for the outcomes. Mr. Marcos Gabriel Alegre Chang, Vice Minister of the Environmental Management Division in the Ministry of Environment of Peru, then gave the Welcome Remarks where he linked the 2016 APEC Central Theme "Quality Growth and Human Development" to food security and climate change, underlining the importance of sustainability and data. Mr. Chang invited the experts in building and enhancing a recent project on connecting various environmental databases, highlighting the cooperative nature of such efforts. The opening ceremony was followed by a gift giving ceremony between APCC and the Ministry of Environment and SENAMHI.

Keynote Session

5. The Keynote Session commenced at 10:00 a.m. and consisted of keynote presentations by two distinguished food security specialists. The session was chaired by Dr. Jin Ho Yoo, the Head of the Climate Prediction Department at APCC.

6. **Dr. Ana María Loboguerrero Rodriguez, CGIAR Research Program for Climate Change, Agriculture and Food Security, "Reducing risks to food security from climate change"**

   Dr. Ana María Loboguerrero Rodriguez, the Regional Program Leader for Latin America of the CGIAR Research Program for Climate Change, Agriculture and Food Security (CCAFS) at the International Center for Tropical Agriculture (CIAT) launched the conference with strong messages about the diverse range of impacts of climate change on food security. She began with a look at CGIAR and CCAFS, which is one of the research programs in CGIAR, and gave an overview of their approach and activities in Latin America which is one of five regions they work in.

Loboguerrero then gave a sobering introduction to the challenges facing food security, highlighting the often paradoxical requirements such as the need for 14% more food per decade, yet more than 1.5 billion people live on degraded land and studies are showing global yields are already decreasing because of climate impacts. While 41% of adults suffer from micronutrient deficiency or are undernourished, 34% of adults are overweight. She stressed the need to think about these challenges now, rather than in 20 years and from both adaptation and mitigation perspectives. Agriculture must do its part in emissions targets, as "Business As Usual" projections for 2050 would have agriculture emissions making up 70% of the 2015 2°C target.

Loboguerrero then expanded on central knowledge limitations. From a modelling perspective, both climate and crop models each show a huge amount of uncertainty, which is compounded in climate-crop models, indicating the need for immediate improvements. She also stressed that there is a chronic lack of attention to livestock, fisheries, pests and diseases, and the interactions between the various components. Across the field, Loboguerrero argued that there is a disproportionate focus on production, which is exemplified in the topics covered by food security chapter of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. There is insufficient attention given to crops as components of larger farming systems, value chains or landscapes. Similarly, she found a lack of attention to broader food security determinants; availability, access, utilization and stability also have impacts on the whole food system. New food systems should look at demand-side solutions, particularly in terms of food wastes and diet. Loboguerrero highlighted the fact that while there is a lot of analysis and modelling being undertaken, it may actually be leading to a form of action paralysis instead of catalysing the solutions and implementation needed.

Following this, Dr. Loboguerrero explored the impacts of climate change on food security. She noted that, despite all the uncertainties discussed, we are observing an average reduction of global crop yields of rice, maize, and wheat. We also expect to see reductions of the quality of food, in terms of micronutrients and protein, linked to increased levels of carbon dioxide. Access to food will be endangered by price increases, and would disproportionally affect the poor.

Loboguerrero outlined four challenges to moving towards an action agenda. The first addressed the need to change the culture of research to focus on action. One difficulty is that incentives reward the publication of papers over solving problems and achieving outcomes. She also explained that focusing on current climate variability disables the excuse that climate change is far away, encouraging immediate action. The second challenge is deriving stakeholder-driven portfolios of options for farmers, communities and countries to enable careful prioritization of short-term action. The third challenge is ensuring that adaptation actions are relevant to those most vulnerable to climate change, in terms of gender and social integration, ensuring that the differential vulnerabilities are addressed appropriately. She noted that gender affects individuals and families' exposure to risk, as well as their access to and control of resources, finance, land, technology, and services. The last challenge is combining adaptation and mitigation needs while ensuring food security. This reflects the difficult balance

necessary in increasing production, while also reducing greenhouse gas emissions in order to obtain sustainable food systems and meet climate goals.

In her presentation and in response to questions from the audience, Loboguerrero also shared their successes with the Climate-Smart Village Approach, a community approach towards sustainable agriculture development. It was described as a scalable initiative to bring together global and locally-relevant knowledge on CSA practices, technologies and services; and institutional and policy interventions that synergistically build the resilience of smallholder farming communities to a variable and changing climate, and where appropriate reduce greenhouse gas emissions.

7. **Ms. Laura Meza, FAO Regional Office for Latin American and the Caribbean, "Climate change and food security: policy recommendations"**

Ms. Laura Meza, Expert Advisor to the Food and Agriculture Organization of the UN (FAO), Latin America and Caribbean Regional Office, began her talk noting the heterogeneous nature of the audience, representing both science and policy, is an important first step in building common ground. Meza shared the primary definition of food security from FAO where "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life," and the four dimensions: availability of sufficient quantities of food of appropriate quality; access by individuals to adequate resources; utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being in which all physiological needs are met; and stability over time ensuring reliable access to adequate food at all times, for populations, households or individuals. Meza also explored the duality of the problems that face us: Current projections estimate a need for 60% more food to feed the expected 2050 global population of 9 billion, yet malnutrition, including both over- and underweight issues, currently costs 2.5 trillion USD to the global economy per year. We need an aggressive mitigation scenario to keep the temperature rise below 2°C, yet we also need to increase production. She highlighted that agriculture is both part of the problem and the solution, and that large opportunities for mitigation exist with livestock and land use management, carbon dioxide storage in soil and biomass, and changing consumption patterns. The World Bank estimates that climate change could add more than 100 million people living in extreme poverty by 2030 due to reductions in agricultural productivity and income. Meza outlined the following five critical issues at the interface of climate and food security: Improving analysis of climate nutrition-health links; a growing need for systematic climate-food-water analysis; exploring co-benefits versus trade-offs; understanding the trends and tackling trade-offs if necessary; and mainstreaming adaptation into development.

Meza then discussed the impact of climate change on food systems and trade, explaining that climate change will cause food production on average to fall, change trade by reducing exports and potentially requiring increased imports, is expected to

increase price volatility, and finally that mitigation efforts could further impact food trade via international agreements and other ambitions approaches.

Meza next explored specific policy recommendations as well as developing an enabling policy environment. She first focused on the need to support farmers, fishers, and foresters now. She listed knowledge of alternative or improved production systems and management options, strengthening local support institutions or mechanisms, making more resilient varieties available through research and development, and enhancing access to resources. She also stressed the importance of communication and the need for two-way science-policy dialogue, highlighting the importance of matching evidence of climate impacts to the needs of policy-makers and harmonizing climate concerns with trade policy.

Meza then outlined FAO's work on climate change, explaining how FAO supports capacity building for transformation change in agriculture, from the local to international levels. She listed a number of initiatives, papers, networks and financial mechanisms that FAO is involved in, promoting sustainable agriculture.

Session I: Utilizing Climate Science in Agriculture - Impacts of Extreme Weather and Climate Events on Agriculture

8. The afternoon session of September 16 commenced at 13:00. Session I discussed the impacts of extreme weather and climate events on agriculture, and was chaired by Dr. Alexander Ruane from the Climate Impacts Group at the Goddard Institute for Space Studies (GISS) in the National Aeronautics and Space Administration (NASA).

9. **Prof. Elwynn Taylor, Iowa State University, "Subtle climate shift, major agricultural impact"**

   Prof. Elwynn Taylor set the stage for the conference with the essential questions on climate change: "How much, how fast, and how come?" He stressed that we are moving in the climate system to areas that require action. Taylor explored what he called the "vicious cycle" where agriculture influences climate, which influences people, which influences agriculture and so forth. The bonds between society and agriculture are necessary, but the impact of people on the climate can be changed. To address the often paradoxical needs of climate and food security, Taylor stressed the need to reduce the expectation that as you get wealthier you use more energy. For example, the average person in the US today uses less energy per than those in 1970. He emphasized the need to move away from fossil fuels towards biofuels, proposing that agriculture and biofuels are the solution to climate change. Taylor then looked at diminishing yields of grain, suggesting that nighttime temperature, if too warm, is a critical yet often overlooked culprit, giving examples from the US as well as the Philippines. He stated that a key agricultural interest is to manage the climate risk to crop yield and strengthening the ties between scientists, boundary organizations (including extension workers) and farmers to help communicate and manage this risk. Taylor suggested that to date, the only viable solution to the increase of atmospheric carbon is agriculture, through true bio fuel, and noted that while corn is the current crop of choice this may change in the future.

10. **Dr. Ken Takahashi, Geophysical Institute of Peru (IGP), "Prediction of El Niño/La Niña, their diversity and climate impacts in Peru"**

    Dr. Ken Takahashi took a look at the diversity of the El Niño-Southern Oscillation (ENSO) and how appreciating the differences between different El Niño events is necessary for appropriate preparation and response. Takahashi explained that our understanding of ENSO is fairly limited, given our relatively short historical records and that our understanding is complicated by complex geophysical patterns, seasonal patterns, and connections to different types of sea surface, ocean upwelling, and wind anomalies. He argued that the communication to the general public about ENSO must reflect the diversity of El Niño, which can include Extreme, Canonical and Modoki (or Central Pacific), rather than making deterministic statements about probabilistic

information. Interactions between the three-dimensional nature of ENSO introduces additional uncertainty even if the event seems to follow previous patterns. Warm ENSO is associated with more rain in Peru. However, depending on where the warming occurs then the anomaly of rain may be positive (warming in Central Pacific) or negative (coastal warming). There is also spatial variability in the local meteorology response, which can create vastly different impacts in terms of flooding and erosion, in turn changing the type of economic impact. Takahashi then described the permanent scientific and technical committee, the Multisectoral Committee of the National Study of El Nino (ENFEN), which issues the periodic official assessments and predictions of ENSO, which includes SENAMHI and IGP. Takahashi also explored the reliability of various prediction models for ENSO, explaining how there are still recurring large problems in the southeast Pacific. He stressed that scientific research in climate aspects is still needed and should not be ignored when pursuing application.

11. **Dr. Govindarajalu Srinivasan, Regional Integrated Multi-Hazard Early Warning System (RIMES), "Operationalizing the use of weather and climate information for agriculture in Asia"**

    Dr. Govindarajalu Srinivasan took an action-oriented approach and shared key experiences from Asia in operationalizing weather and climate information. He began by giving a background of RIMES, which is an intergovernmental organization that links science with the generators and users of early warning information. Srinivasan discussed the challenges in operationalization, a necessary role of boundary organizations, where we try to translate science and technology into services that should be able to influence decisions. This must be delivered at an appropriate complexity in tailored solutions to maximize beneficial impacts. He also stressed the importance of building and maintaining trust. Srinivasan then outlined a case study of a United Nations Economic and Social Commission for Asia (UNESCAP) project in Myanmar, which focused on developing an Agro-Met Data Management and Advisory System and capacity building. He gave an overview of the way that the UNESCAP project was carefully developed to match the needs of the region to deliver agrometeorological bulletins and short term forecasts by collecting input from farmer field schools and government. He stressed the importance of engaging extension workers at township level and coordination across government levels from provincial to national. To summarize lessons learned with operationalization, Srinivasan highlighted the need to identify how climate information is generated, shared, and used, to properly look at and address gaps, and to use demonstration projects as a solid beginning.

12. **Dr. Julian Ramirez-Villegas, International Center for Tropical Agriculture (CIAT), "Using crop-climate modelling for adapting cropping systems to climate variability"**

    Dr. Julian Ramirez-Villegas spoke about his experiences with CIAT in using crop-modelling and highlight some success stories from Columbia for decision-making at

the farm levels. He began by sharing how agriculture depends on climate, noting that a recent study shows that climate drives more than a third of all yield variation, illustrating the fact that our systems are sensitive to climate rather than resilient. Although climate is not the only factor, we need to learn how to manage this variability. Ramirez-Villegas then explained how CIAT works with local and national governments to help farmers, governments, and private sector prepare for climate variability and climate change. He took a closer look at some activities under a technical and scientific cooperation agreement between the Columbian Ministry of Agriculture and Rural Development and CIAT. The agreement aims to close yield gaps through the appropriate management of climate, minimize crop losses due to climate variability, and produce food sustainably and synergistically with the environment. In particular, Ramirez-Villegas looked at the implementation of climate-smart management to close yield gaps by mining Big Data from rice farms to provide a bottom-up approach to improved rice crop management. This approach of Big Data analysis and data-driven agronomy, where data was mined from a large number of private rice farms, is arguably the next big revolution in agriculture. Additionally it showcases how the private and public sector can collaborate in a win-win scenario for great results in a short amount of time. Ramirez-Villegas then shared a success story of generating agro-climatic seasonal forecasts for rice producing regions in Columbia using statistical forecast models and validated crop models. In this instance they predicted decreased rainfall and increase temperature to recommend an optimal planting date, which saved a large amount of rice from intense drought for 170 rice farmers.

13. **Dr. Alexander Ruane, Climate Impacts Group NASA GISS, "Climate application for agriculture and food security"**

Dr. Alexander Ruane explored the concept of risk, noting that risk is dependent on the hazards, the exposure of your system to the hazard, and vulnerability of your system to that event. This means that risk depends on both climate and socio-economics and, while it reveals the complexity of risk, it also shows that there are many different leverage points in addressing risk and is an opportunity for intervention. Ruane then argued that we need three pillars of agricultural monitoring and assessment: on-the-ground observation networks, remote sensing, and crop modelling. He then shared the Agricultural Model Intercomparison and Improvement Project (AgMIP), which is organizing community efforts to improve and link models to understand risk factors. They are working to connect climate, crop, livestock, economics, food security, and nutrition to understand the linkages. AgMIP is addressing the triple burden of the agricultural sector: adaptation, mitigation, and balanced production. Ruane then discussed major new developments in agricultural modelling but noted that there are large limitations in climate and agricultural information. He stressed the need for more data, especially as much of research is focused on small centers of production rather than more general small-scale production, which is also critical for food security. He also highlighted the potential for crop model to augment existing agricultural

monitoring and assessment systems, saying that there is a great need establish modeling setups that may be utilized for forecasts, retrospective analysis, and scenario assessment.

14. **Dr. Kwanghyung Kim, APEC Climate Center (APCC), "Improving agricultural resilience to climate variability through ensuring data availability and enhancing agro-meteorological services"**

Dr. Kwanghyung Kim presented on successful practical application and shared lessons learned from building and enhancing agro-meteorological services for decision-making. Kim noted that decision makers need to manage the risk of a variable climate, but that vulnerable populations require tailored information and appropriate connections to technologies and practices that optimize results. He then gave an overview of Climate-Smart Agriculture (CSA), which promotes food security, adaptation, and mitigation. CSA can also be thought of as the smart use of climate information for making decisions relating to a climate-sensitive process. Kim then gave a hypothetical case study of "Farmer Smart," who illustrated the need for a long term approach to CSA, given the inherent uncertainties in climate information. He also noted the critical need for data, upon which CSA depends, and stressed the need to enhance climate services. Next, Kim shared examples of successful use of various agro-climate decision-making tools with APCC in Tonga, with the Tonga Climate Services for Agriculture, for a rice disease early warning system in the Philippines, as well as with Kiwifruit growers in Korea. All examples highlighted the essential need for climate data to develop weather-yield relationships. Despite extremely heterogeneous geographic conditions, the Kiwifruit growers were able to build highly tailored recommendations over many years by inputting their own data through a mobile-based crop-climate diary. Compared to the prediction based on the original input data, the personalized prediction was more accurate. This shows that these services can be iteratively improved with data generated by the users themselves. Kim also stressed the need to make useful and easy ways to do this, for example by integrating the generation of an export document for compliance requirements with the crop-climate diary in Tonga. Finally, Kim explained how APCC develops climate services, works with practitioners, shares climate information, and prioritizes trainings and collaborations.

15. **Dr. Roberto Quiroz, International Potato Center (CIP), "Assessing the impact of climate change on potato cultivation in its center of origin"**

Dr. Roberto Quiroz gave a presentation on assessing the impacts of climate change in the center of origin of the potato, while exploring how key lessons can be learned from farmers who are veterans at managing climate variations and extremes. He first noted that that extreme events will become more frequent and of greater impact, underlining our need to develop solutions for coping and adapting for future challenges. Then, Quiroz gave a brief overview of how crop models are developed and how they can be used to understand the impacts on crop production. He then looked at the potato center of origin in the Andes, where many lessons have been learned in understanding what

farmers to with climate information and what kind of adaptive responses they have. One major finding was the importance of a diversified portfolio for resilience, where they use a large mix of varieties and staggered planting, plant at multiple elevations, and employ a range of management and breeding strategies. Quiroz also showed how the impacts of climate change can already be seen in the upward movement of crops, as higher and higher elevations are necessary. He then discussed how CIP is developing practical, economical, and ecological solutions for pest and disease management including integrated pest management.

16. **Wrap-up and Discussion:**

The discussion session began with a question from Dr. Maximo Torero, noting that the human component of the adoption of these climate smart strategies was not addressed. Dr. Jake Rice asked about their experiences in dealing with asymmetry making policy decisions based on this type of information, where an error from inaction is perhaps less dangers and an error in acting when one shouldn't due to a false alarm. Ramirez-Villegas agreed that the adoption of these practices is definitely a problem but that an approach, not of fundamentally changing the system, but building better recommendations or tailored modifications, can be received more readily. Srinivasan highlighted the role of visible early-adopters while Taylor underlined the business nature of farming. Quiroz, Ruane, and Taylor all stressed the importance of the human dimension and good communication. Takahashi shared an experience where trust was built when they shared the projections for a low probability but high risk event, so that the government could make early decisions. Mr. Micha Rosenbug elicited views on how to integrate nutrition into these models, as it was a central concern for food security. The speakers noted the difficulty and uncertainty in integrating nutrition into models or projections, saying that it is currently behind us. Prof. Heekyung Park asked for and received clarification on the day and night temperature as discussed by Taylor, where the importance is the difference between day and night temperatures rather than the specific value.

Dr. Ana Maria Loboguerrero then noted that extension workers have a minimal presence in Latin America, and asked for shared experiences. Kim noted that there are not strong extension services in Tonga, with low technical capacity, but through a collaboration with the government were able to use extension workers to collect critical data rather than creating new positions. Ramirez-Villegas agreed that extension services are a key delivery mechanism when present, but you can find other methods if it is absent. In one of the CCAFS projects we mapped information flows. In some cases we realized that it is the "visionary farmer" that people listen to, or radio, who was the key delivery mechanism. He shared a success story in Senegal where use the radio to teach directly to farmers. Srinivasan noted that extension services are not always established, but farmer organizations and other similar institutions can be used instead.

Ruane, recognizing that the session focus was on extreme weather events, inquired if there is an issue they feel is important but is not getting enough attention. Srinivasan referenced the many gaps that were addressed in the presentations. Takahashi said that,

while it is a bit unrelated, an ecosystem collapse in the amazon because of drought really worries him. In the next fifty years, part of the amazon could become a savanna, which is a low probability but very high risk event and needs more attention. Quiros noted that most of the climate models have been developed with the physics of developed economies, which is where the data comes from. He stresses the importance of data in importing these climate models into emerging economies. Kim noted that many of the policy recommendations developed by scientists are not actually taken up by policy-makers. Ruane cited the potential for multiple breadbasket failures, as the food systems have not been tested under the sort of conditions where multiple failures occur in the same year.

Ruane then inquired about what leaves the experts optimistic. Srinivasan noted that compared to something like health, agriculture is actually a great field in terms of data availability and interest. Taylor noted that the harshest years in North America appear to be on a cycle of an average of 89 years, with the last one in 1936 we are nearing the next date of 2025. Ramirez-Villegas cited a range of progress being made in technology, data, and inclusive approaches. Quiroz explained how visiting ancient communities and seeing what harsh conditions people have adapted to gives him hope that humanity can face any challenge, especially with the comparative analysis of models now available to the young generation. Kim shared that the perspective of the scientific community is shifting with the changes in funding mechanisms, as there is a good shift towards practical and policy-relevant results, rather than purely scientific. Ruane closed by stating how he is continually impressed with farmers, as if you give them enough warning there is more ingenuity and ideas that one would expect. He is also optimistic about computing power and telecommunications to allow us to address these challenges in new ways.

Session II: Employing Climate Science for Long-Term Agricultural Planning

17. The morning session of September 17 commenced at 09:00. Session II discussed the use of climate science for long-term agricultural planning and, was chaired by Dr. Maximo Torero from the International Food Policy Research Institute.

18. **Dr. Toshichika Iizumi, Institute for Agro-Environmental Sciences, National Agriculture and Food Research Organization of Japan, "Growth and variability of crop production under climate change and socioeconomic pathways"**

    Dr. Toshichika Iizumi presented on the current status of global agriculture, and both current and projected yield growth and variability. He began by outlining that cropland and pasture already account for more than a third of the earth's ice-free land, use almost 70% of global water withdrawal, and produces an important percentage of anthropogenic greenhouse gas emissions. This information, combined with the fact that yield growth is currently projected to be insufficient to meet the expected global needs in 2050 and the threat of climate change illustrate the serious challenges ahead for food security. Iizumi then posed the question: have recent changes in daily temperature and precipitation extremes had a measurable influence on yield variability? To address this, a global dataset of historical yields was analyzed showing that there was increased yield variability in 9-22% of harvested area but he noted that a large amount of area displayed decreases in yield variability, showing the complexity in how these systems are responding to climate change. Iizumi then posed the question: how does crop production growth respond to climate change, particularly warming from pre-industrial levels? The central tool used was a global gridded crop model (GGCM) and they found that many low-income economies would experience a stagnation of production growth if global temperature change exceeds 1.7 °C above pre-industrial levels. However, he noted that many high-income countries could maintain production growth even under a warming of 4.7 °C. In all, he concluded that agricultural development (or adaptation) in some regions in the last decades is insufficient to offset the negative impacts of observed climate change. He also stressed that long-term global yield monitoring and a better understanding of the contributions of technology, management, policy, and climate to ongoing changes in yield trends and variability are necessary to guide national agricultural adaptation.

19. **Dr. Mark Howden, Australian National University, "Seasonal climate forecasts as a pathway for climate change adaptation: a review"**

    Dr. Mark Howden presented a critique of seasonal climate forecasts, not of the forecasts themselves, but in the way they are sometimes used and presented. If used optimally, seasonal climate forecasts can be telescopes into the future, allowing users to adjust autonomously to year to year variations in the frequency of extremes. However, there

are challenges in effectively communicating the forecasts and uncertainties, as well as interpreting probabilistic information in a deterministic manner. Howden emphasized that we must be careful about how we use seasonal climate forecasts, listing six negative dimensions of incorrect application where they can be uncertain, distracting, misleading, unnecessary, or divisive. He outlined how via data limitations, model biases and gaps, internal variability and other factors it is often uncertain how uncertain the forecasts are. This uncertainty, which can also change with time, must be conveyed properly so that a deterministic interpretation of this probabilistic information that could lead to disengagement can be avoided. An understanding that seasonal climate information is necessary but one of many elements that should be considered when making decisions. Howden stressed that recognizing that alone it is insufficient and should be used to augment the knowledge of decision-makers. Next, he explained how seasonal climate forecasts can actually be distracting as they can eclipse other important approaches such as scenario exploration. He then described how seasonal climate forecasts can be misleading. By choosing a specific metric, such as rainfall or maximum temperatures, the focus is shifted perhaps at the expense of other important factors. He also noted that forecasts are often provided even after the uncertainty becomes too great, rather than communicating this uncertainty. Howden then stressed the need to assess appropriately if these forecasts add value to whatever activity is being done and enhance capacities to make decisions under uncertainty, to avoid the unnecessary use of seasonal climate forecasts. Finally, he then explained the potential for seasonal climate forecasts to increase inequalities among farming populations, generating their divisive dimension. In sum he expressed the need for significant additional research on the use of these forecasts rather than just the forecasts themselves to increase their effectiveness as a boundary object.

20. **Dr. Ho-Young Kwon, International Food Policy Research Institute (IFPRI), "Global adoption of climate-smart agriculture: ex-ante economic impact assessment"**

Dr. Ho-Young Kwon shared pertinent research on how the global adoption of climate-smart agriculture could facilitate agricultural adaptation while simultaneously mitigating climate change-induced price increases. He began by describing how food security challenges are unprecedented, compounded by population growth and income growth in developed economies, generating more demand for high-valued food. Kwon explained how climate-smart agriculture (CSA), which combines the two concepts of climate change adaptation and mitigation, can increase sustainable productivity with a more efficient use of inputs, resulting in a likely reduction of emission intensity (emissions per unit of output). He then detailed a study looking at the effect of CSA on the global economy where ex-ante biophysical and economic impact assessment is performed using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) system of models. The study showed that CSA has the potential to improve how agriculture response to climate change. However, because of the complex global interactions between price, demand, and derived demand for

cropland, along with an assumption that adoption of CSA practices can only occur where there is a positive yield effect compared to business-as-usual practices, it showed that CSA does not seem to contribute significantly to GHG emission reduction necessary to meet the 2°C goal. Kwon suggested that if reducing emissions increased in focus relative to increasing productivity, a more systemic view of agricultural development linked with land use changes would be required. He noted that CSA is supposed to be a different approach to agricultural production, not necessarily a proscribed set of practices, and it has the potential to foster a more comprehensive approach to increasing productivity in a changing climate. While he noted that the transition to CSA is afflicted by familiar barriers relating to risk, uncertainty and imperfect markets, this also generates an opportunity to open dialogue across ministries and reinforce the importance of a multi-objective approach in agricultural policies.

21. **Dr. Maximo Torero, International Food Policy Research Institute (IFPRI), "Scenarios on climate change impacts for developing APEC economies and how to increase resilience and benefit from opportunities"**

Dr. Maximo Torero looked at how to increase the resilience of food systems and benefit from opportunities presented by climate change in APEC economies using an analysis of various scenarios to find expected impacts on factors such as price and yield. To begin with, he looked at how climate variability and risk will have diverse impacts globally. There is moderate consensus that temperate regions will have increased variability in temperature and rainfall but no consensus on tropical regions, though he noted that increase mean temperatures means risk increases. Torero showed that, while there was a consistent increasing trend between different scenarios, the changes in climate change price impacts exhibited great variation, which causes complexities for economies in trying to interpret these results develop plans. He explained how trade will play a central role as it is both part of the problem and part of the solution. The former is driven by an increase in emissions, the creation of markets which connect new demand to new supplies and can cause severe environmental damage, as well as increased transport impacts. However trade can also be part of the solution, as it does not necessarily mean more produce but could be different and potential better. He cited the example that there could be less intensive production used, where a Spanish tomato consumed in England has a quarter of the carbon footprint of its British cousin. Torero then gave the results of his projections for the 21 APEC member economies, noting the heterogeneous impacts on various crop yields and world prices, and gave an overview of the effects on fisheries. He then discussed climate smart policies, explaining that we already know the big picture but the details need more evidence. The familiar big picture items are accelerating investments in agricultural research and development for productivity growth and climate resilience; increasing investment in rural infrastructure, regulatory reform in seed and input markets, and improving extension services; and final reforming economic policies on open trade, land and water rights, and reduction of relevant subsidies. Torero then outlined the need for more analysis on the degree of "climate smartness" of various approaches, to reveal impacts through analysis that are

not apparent in market signals, and encouraged the spatial disaggregation of these analyses. He concluded by explaining how CSA changes the planning time horizon and forces us to shift the emphasis from policies that aim at a single target to policies that have multiple objectives, supporting a more nuanced approach to planning.

22. **Dr. Willingthon Pavan, University of Passo Fundo, Brazil, "Climate information tools for decision making"**

Dr. Willingthon Pavan presented on a range of climate information tools to support farmers and crop advisors in agricultural decision-making in Brazil. He began with a description of the Mosaico Research Group's activities, where they integrate climate, forecasts and production systems to develop systems that help growers make decisions. He then discussed how Disease Forecast Systems are developed, focusing on the three aspects of disease: environment, host, and pathogen. Pavan started with a discussion of information tools to gather data about the environment, introducing new efforts such as the Weather Stations Network and the Leaf Wetness System. He noted that key concerns are to ensure that the collecting tools are inexpensive enough so that damage in the field can be absorbed. They focus on service-oriented architecture and data storage technology. He then explored the advances in remote sensing using satellites and drones, which can then be integrated into geoportals. Pavan then took a look at how one can collect data on pathogens, introducing successful information tools such as the Pic-a-Wheat Field smartphone application, which encourages wheat blast surveillance and assists dispersion tracking in Brazil. Similarly, an Anti-rust consortium collects and displays a huge amount of data on rust occurrence in Brazil, allowing for dispersion tracking. Pavan then took a look at how we gather information about the host, covering methods such as crop models, the use of images to gather high resolution understanding of phenotypes or blooming detection software. He then brought these approaches together, looking at tools which integrate this information to help crop advisers and farmers to make decisions, such as Sisalert. This multi-platform app forecasts plant disease risk in Brazil, similar to how the Strawberry Advisory System in the US alerts for Botrytis and anthracnose risk. Finally he talked about how all of this can be integrated, using the Agricultural Model Intercomparison and Improvement Project (AgMIP)-Pest as an example of pest and disease coupling.

23. **Dr. David Ellis, International Potato Center (CIP), "Is agrobiodiversity a key to sustainable crop production in a changing environment?"**

Dr. David Ellis explored the potential of agrobiodiversity to support sustainable crop production, using CIP's work with the Parque de la Pap to highlight the opportunities and successes. To begin with, Ellis discussed the role of diversity in agriculture, which he explained is the driver of crop domestication, improvement, and genetic gains, as it is the source of new traits. In the Peruvian Andes, diversity has been used for millennia as a type of insurance, where the farmers plan multiple varieties of potatoes. However, Ellis noted that this system is breaking down. To counter this trend and provide support

to communities both local and international, genebanks conserve crop diversity. The CIP in-vitro genebank stores clones to distribute globally for research straining and breeding. He explained how these resources, which include breeding lines and land races, belong to humanity and are distributed freely. Ellis then described CIP's 10 year partnership with the communities in Parque de la Papa, which is home to subsistence farmer using traditional methods and varieties. Using participatory methods, they have performed a number of trials, producing critical information on the impacts of climate change and the appropriateness of difference varieties. Despite some initial resistance or disinterest, CIP has found that the repatriation of varieties back to communities has been critical in ensuring sufficient amounts of local diversity and has created a mutually beneficial exchange both ways.

24. **Eng. Grinia J. Avalos Roldán, National Meteorology and Hydrology Service of Peru (SENAMHI), "Implementing climate information services for decision-making in Peru"**

Engineer Grinia Avalos Roldán presented on the Global Framework for Climate Services (GFCS) and the implementation of climate information services for decision-making in Peru, illustrated by SENAMHI's work with mango growers. Avalos began by outlining the goal of GFCS, explaining that the framework is designed to mainstream climate science into decision-making at all levels and help ensure that every country and every climate-sensitive sector of society is well equipped to access and apply the relevant climate information. She also detailed the priority areas, which includes food security, and the pillars of GFCS. Avalos then discussed agriculture in the highlands of Peru, starting with principal climate events and their impacts and then outlining the target population. They were looking at around 150,000 producers, the majority of whom speak a native language, with low literacy among women. Most use low production cost and mono crops, however more than eighty percent say that profits do not cover their needs. Next, Avalos characterized the impacts of El Niño on agriculture, specifically for a case study of the Lambayeque mango crop. She noted that there is a vulnerability of production to climate variability, as mangos depend on thermic factors for flowering and are sensitive to precipitation occurring during crop season. She also noted that there is increasing vulnerability due to the atomization of croplands. To address these vulnerabilities, SENAMHI developed a climate service for the mango crop to monitor thermal conditions for mango cultivation by producing seasonal probabilistic forecast. They discovered that weather is an important factor but noted that agronomic management is also important. They found that different thermal conditions coupled with floral induction strategies helped ensure the prevalence of higher levels of bloom compared to previous yields. They hope to expand this and provide reliable and timely meteorological and hydrological products and services.

25. **Wrap-up and Discussion:**

The discussion period began with a question from Dr. Ana Maria Loboguerrero for Kwon about his suggestion that the implementation of CSA could reduce prince increases and that it was not as effective in greenhouse gas reduction, which is a product of the CSA practices that were picked. Kwon said that the main point he showed was that the price change can be mitigated by adopting CSA, and noted that because this is a global average and these techniques are applied all over the word, the reduction in greenhouse gas emissions in some places like India, using the alternate wetting and drying method, is balanced by modest changes in others. Dr. Dimitri Gutiérrez then inquired about the use and application of transgenic plants in climate change adaptation. Ellis responded that any tool that we have in our agricultural toolbox needs to be considered in addressing climate change, and that we cannot exclude current or future technologies as we need everything. Torero included that we need to have a portfolio of options with solid evidence, as well as institutions in place to provide support.

Mr. Samuel Maiha from the Papua New Guinea National Weather Service asked if the speakers had considered scenarios of the unlikely but important concurrent concentrated failure of multiple centres of production for a staple crop. Torero acknowledged that the world market is highly concentrated in terms of production, causing specific exports, and that 60-80% of production is focused in one center for many staple grains. This is definitely something that is being considered, as well as being addressed by newer institutions like the Rapid Response Forum of the Agricultural Market Information System, designed to address crises like that.

Monica can Wensveen from the Australian Department of Foreign Affairs and Trade noted that she was alarmed by the fruit and vegetable yield drops from a perspective of nutrition and asked how they would navigate the policy space specifically from this perspective. Torero noted that he was also alarmed, and that there are two approaches he would suggest. First that there is a need to understand the level of distortion of the commodities and using this data to try to show what incentives for staples and others are affecting, and what would happen if this money for incentives was moved around. Second, he suggested creating a platform for reducing losses across the value chain.

Dr. Kwanghyung Kim noted that there is often a huge gap between scientific results and their uptake, and asked the speakers to share any success stories. Torero began by explaining IFPRI is a policy center, with a range of successes and failures. He explained that these successes can occur when you convert the scientific information into what is important for the other party. He gave the example of recently bringing together finance ministers from across South America to discuss food security with agriculture ministers. He felt this happened because they spent a long time costing out what malnutrition and other related problems means, making this issue relevant from a financial viewpoint. Kwon said that there are many success stores, like the use of climate agricultural data in the Intended Nationally Determined Contributions to the 21st Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), but noted that communication is key.

Dr. Govindarajalu Srinivasan brought the conversation to focus on insurance and climate risk management, wondering how the speakers see this progressing in years to come. He noted that, particularly in Asian countries, he has seen a very slow uptake.

Torero explained that the index approach was created to address these issues, where index insurance is insurance that is linked to an index, such as rainfall, humidity, temperature or crop yields, rather than actual loss. They need to face two issues: reducing basic risk and also reducing the cost. This can be addressed by mixing approaches and diversifying portfolios. Pavan shared an experience working in Paraguay, where tools were created and provided, which help farmers be more competitive, giving incentive for adoption.

Ana Maria Loboguerrero then discussed the long-term agricultural problem. She inquired how, in their experience, have the experts present transmitted the long-term model when talking to farmers. She noted the difficulty in talking about 50 years ahead and asked about how this has been addressed, or if we should avoid this and focus on climate variability. Iizumi supplied an example of long-term fruit producers, where in Japan some farmers use an individual tree for 30 years, so they are thinking about the long-term. However beyond specific crops, he noted that the use of long-term information may not be for farmers, but rather for policy making and government bodies. Kwon stressed the importance of using appropriate language depending on the target and agreed with Iizumi in saying that the long-term information is for policy makers, but we can use this and extract key points for farmers. Pavan said that in his experience, some key producers are interested in the long-term future, but there are many others who are afraid and reluctant to adopt new technology. He noted that some don’t even believe in climate change. Grinia stated that they communicate graphically how things are changing or will change, which helps them to cope with variability.

Session III: Long-term Solutions for Threatened Fisheries Caused by Climate Change

26. The afternoon session of September 17 commenced at 15:00. Session III discussed long-term solutions for threated fisheries caused by climate change and was chaired by Dr. Johann Bell from Conservation International.

27. **Ms. Lauren Weatherdon, United Nations Environmental Program (UNEP) World Conservation Monitoring Centre, "Where are the fish? Reducing climate impacts on coastal communities and marine industry"**

Ms. Lauren Weatherdon opened the third session by giving a comprehensive overview of the impacts of climate change on marine ecosystems and consequently marine food security, delving into issues such as nutrition and approaches like coastal ecosystem based adaptation, before looking at the next steps that can be taken. She began with an introduction to the UNEP World Conservation Monitoring Center, which centralizes biodiversity in decision-making processes by providing data, information and knowledge to support critical change in environment and development policy. Weatherdon then explored the impacts of climate change, explaining that major changes in sea surface temperature (SST) are already occurring and that we are expecting changes in maximum catch potential, with fish moving deeper and towards the poles. She noted that these outcomes will not only affect ecosystem functioning, but also the quality and mean size of fisheries' landings and the availability and quality of seafood. Weatherdon elaborated by giving examples of how all dimensions of marine food security will be affected: availability because of changes in habitat; stability though changes in seasonality, productivity through changes in ecosystems; access through changes in livelihoods; and utilization as consumers adjust to non-traditional species and increased frequency of disease. She noted that fish are an important source of micronutrients, which have a significant effect on development and health, and thus cannot be easily substituted by other sources of protein. Weatherdon explained how aquaculture, particularly in equatorial regions, can adjust to climate change. She also detailed ecosystem based adaptation and blue carbon approaches. Finally, she stressed the interconnectedness of ocean health, food security, economics and human wellbeing.

28. **Dr. Johann Bell, Conservation International, "The effects of climate change on the contributions of fisheries and aquaculture to food security"**

Dr. Johann Bell spoke about the impacts of climate change on the contributions of fisheries and aquaculture to food security. He posed two key questions. How is climate change likely to affect the plans being made to provide the additional fish required by growing populations? What adaptations will be needed to reduce the impacts of climate change and capitalise on opportunities? He used the Pacific Island region as a case study and began with an overview of the projected impacts of climate change on coral reefs, mangroves, and seagrass. Coral reefs will be eroded by increased ocean acidification

and increased sea surface temperatures will cause coral bleaching more frequently. The mangroves of the region are vulnerable to sea-level rise and increased storm intensity, and are projected to decline by 60 percent by the end of the century, whereas seagrasses are expected to decline due to warmer waters, increased rainfall, and increased storm intensity. Bell then explored the impacts of climate change on changes to food webs for tuna, noting that primary production in the Western Pacific warm pool is likely to decrease to due to increased stratification of the water column, but the strong upwelling in the Pacific equatorial divergence is likely to continue. He also talked about projected changes in the location of the preferred feeding zones of tuna, which are expected to shift progressively eastwards, as occurs during present-day El Nino events. The expected changes in the distribution of tuna has important implications for several Pacific Island countries because of their high reliance on licence fees from industrial fishing fleets. Finally, Bell suggested a number of "win-win adaptations" that address important drivers of the fisheries sector in the short term, and climate change in the longer term. These adaptations involve: enhancing the resilience of fish habitats, e.g., by managing and restoring vegetation cover in catchments, and providing for landward migration of mangroves, to enhance the resilience of coastal fish habitats; sustaining the productivity of coastal stocks, and increasing access to tuna to relieve fishing pressure on coral reefs. He also suggested expanding pond aquaculture by scaling up the development of tilapia farming. Bell also stressed the importance of building supporting policies.

29. **Prof. Elvira Poloczanska, Alfred Wegener Institute, "Current and future situation of Australian fisheries to climate change"**

Professor Elvira Poloczanska gave a presentation on the future implications of climate-drive range shifts of marine species that are already being observed and took a look at the Australian fisheries. She began by noting that relatively small changes can amplify up through ecosystems and that climate-driven range shifts are observed from every ocean, showing the potential for a large-scale reorganization of the distribution of biodiversity. Poloczanska and her colleagues thus examined global isotherm trajectories and modelled how this would affect the distribution of more than 1,300 species. This research was based on the idea that species will track their shifting thermal niches, with consideration to habit preferences. They found a decrease in biodiversity in the tropics but also found an increase where the range shifts outweighed local extinctions. Poloczanska then spoke about a tool they developed to assess how prepared fisheries are for changes. They combined an ecological vulnerability model of the relevant species with a macro-scale vulnerability model, which covered factors outside the control of fishery businesses like the change in fuel prices, to be input into an overall micro-scale vulnerability model. This will give insight on what the main drivers of vulnerabilities are in the industry, where regulators can have the greatest positive impact, and what fisheries can do to increase their resilience.

30. **Dr. Dimitri Gutiérrez, Ocean Institute of Peru (IMARPE), "Productivity and sustainable management of the Humboldt Current large marine ecosystem under climate change"**

Dr. Dimitri Gutiérrez shared highlights on the productivity and sustainable management of the Humboldt Current large marine ecosystem under climate change, sharing the approaches and insights from Peru. He began by giving an overview of the Humboldt Current large marine ecosystem (HCLME), the most productive eastern boundary upwelling system in the world, in terms of fishing yields. He noted that in Peru, there are around 200,000 people whose livelihoods directly or indirectly depend on HCLME, however that the direct consumption of fish in Peru is low, with a significant portion of yields directed for fish meal and export. Gutiérrez then detailed our current understanding of the ongoing and projected changes for the climate and ocean systems in the region, listing changes in sea surface temperature (SST) trends, acidification, and deoxygenation as some examples. He then examined the status of regional fisheries, noting that the Peruvian fishery is dominated by one species, anchovy, while Chile is more diversified, however both show vulnerability as they focused on a few species. With both weak and moderate El Nino events, they see a high degree of interdecadal variability amond the three anchovy stocks: Northern-Central Peru , Southern Peru – Northern Chile, and Central Chile. He shared that there have been different trends with the biomass and landings of various species, with some declining like the sardine and jack mackerel, but others increasing, like jumbo squid and mahi mahi. In all, Gutiérrez shared some key messages. He stressed a need to improve the scientific knowledge on future scenarios and models that provide details regarding the time period between 2016 and 2050. He also highlighted the need to address pollution hazards for the ecosystems and its resources. He suggested introducing ecosystem-based adaptation to fishery management as well as continuing or improving the effective control of fishing power, and to extend incentives and law enforcement for ensuring good practices and sustainability.

31. **Dr. Rashid Sumaila, University of British Columbia, "Climate change effects on the economics and management of world fisheries"**

Dr. Rashid Sumaila explored the effects of climate change on the economics and management of world fisheries. He began by listing some of the numerous ways that marine ecosystems and fisheries benefit people, including food and nutritional security, recreation, culture, and ecosystem function and services. Fisheries contribute roughly USD 120 billion to the global economy, and around USD 400 billion of added value, playing an important role in economic security. He highlighted that fisheries also contribute to social services and security, employing 260 million people. Sumaila then took a look at the impacts of climate change, with changes expected in catches, food security, catch values, the cost of fishing, profits of fishing companies, income of fishers, and the distribution of benefits to different countries, regions, and groups. He shared studies that project a change in catch and revenue potential in the 2050s, with a loss

expected in the equatorial region. Sumaila then detailed another study on the impact of climate change on the household budgets of British Columbians, investigating how climate change would likely affect British Columbia's stable seafood prices. He concluded that to maintain the current diet in volume and quality, an additional CAD 110 million would have to be spent a year. Sumaila also underlined the food security implications, in particular as fish protein is more valuable than other proteins in terms of nutrition. However, there are other ways of addressing food shortages such as minimizing waste, as half of the fish cooked in the United States of America is wasted. To conclude, Sumaila highlighted the fact that our governments and societies are not anticipatory and do not prioritize prevention. He also noted the inadequate focus on long-term planning because everyone wants benefits now that negatively impact fish. He underlined that all change begins with individuals.

32. **Dr. Jake Rice, Department of Fisheries and Oceans of Canada, "Climate change, food security, and the ocean: is there a path forward?"**

Dr. Jake Rice addressed the largest challenges to marine food security under climate change and explored possible solutions. He began by stressing the difference between agriculture and fisheries, highlighting the critical importance of biodiversity in fisheries and noting that you can only take a sustainable yield from a healthy ecosystem. Rice highlighted the often conflicting needs that must be addressed: protecting ocean biodiversity and increasing yields. The global capture of fisheries has stabilized for more than 20 years, indicating that we will not see an increase and may even see a decrease. However, it is not clear if aquaculture will be able to provide for the additional 75 million tons per year needed to meet the projected global demand for fish by 2050. Aquaculture, which is the fastest growing food system, widespread, does have room for growth but this must be approached realistically and sustainably. Rice stressed that aquaculture would be a major perturbation for coastal ecosystems generating large biodiversity concerns. He explained that although there is a lot of optimism for the contributions of aquaculture, there are few projections on how much aquaculture can expand sustainably. Projecting linear growth ignores all normal negative feedback, such constrictions on resources like land or feed. He noted that most of the information we have is only relevant to medium and large-scale operations, as opposed to small-scale, which is what will be relied on in food insecure regions. Rice then explained the implications for global trade, noting that fish is the most traded food commodity on the planet. This movement of fish from food deficit countries to food rich calls into question the purpose of fishing, as there is an important difference between fishing for money versus food. He concluded by noting that we currently do not have the governance structures to begin this type of discussion.

33. **Wrap-up and Discussion:**

Dr. Alex Ruane began the question period inquiring if the speakers had looked into the fact that many of the resources needed for aquaculture are in direct conflict with those

needed for agriculture, such as water and feed. Rice reflected that while there are trade-offs, if a pond or stream culture is growing fish for community consumption, it becomes a community choice. There are strains of fish that FAO has developed which can survive in what is essentially agricultural waste. He also noted that, in terms of protein, aquaculture is much more efficient than livestock.

Dr. Maximo Torero then asked Rashid about his models, wondering since there was a lot of variability as well as other factors with trade, how does one invest in fisheries and aquaculture or make decisions when there are so many factors that you cannot control, in comparison to the more stable agricultural field. Rashid acknowledged the issue of public perception, where there is a lot of resistance to aquaculture and that there are also many limits to how aquaculture can grow, given the constraints on water and space etc.

Dr. David Ellis then asked whose jurisdiction these strains of fish for aquaculture are. Rice explained the complexity of the issue as they have approached this with very different accountability, and there are varying degrees of alteration of genomes, mentioning the Nagoya protocol. Bell brought up the example of the Nile tilapia, which originated in Africa but then has evolved over its global spread as a key species for pond aquaculture with genetic improvement programs, illustrating the complexity of origin.

Dr. Heekyung Park brought up the concept of using insects as food, and inquired if there was anyone who could elaborate on using insects as a protein supplement. Rice noted that, with regards to the marine equivalent, there is currently a serious discussion on how we can harvest in different ways, bringing up the "balanced harvest" as a possible tool, where species or individuals are exploited in accordance with their productivity, to help balance between biodiversity and fisheries. Sumalia expressed his hope that we do not put future generations in the position where they are required to eat insects and that it is very hard for people to change their behaviours. Bell noted that currently the highest BMI is found in Pacific Island Nations, but that this is a new learned behaviour and can be unlearned.

Dr. Kwanghyung Kim shared his experience at a workshop on CSA a few months ago, noting that a number of individuals from the fishery sectors wanted to know specific prediction on where and how large a shift will be seen in range. Is modelling at a level where this is possible? Poloczanska noted that we are currently looking at how species will move and species composition, but explained that as we are going to see new analogue communities with nothing to compare them to, we cannot predict how they will behave. Gutiérrez said that there is a significant amount of monitoring of the level of fishing stocks by the government in Peru, which represents one of the most intensive monitoring efforts in the world, but is restricted mainly to anchovies. Other fisheries resources, such as coastal species, are harder to survey and this presents a problem in terms of predicting or monitoring the effects of climate change. Rice noted that we have built half a century's worth of data on species' distributions, and so we can now predict with some reliability where species will go in terms of thermal envelope models, but their availability to fisheries is a totally different matter. He said that we can also predict

how the size of fish will be altered as ocean temperatures increase but we will need to make changes in how with think about management.
Bell then brought the conversation back to aquaculture, noting that the way aquaculture is primarily done now is by converting food into higher value food. He sees a real potential crossover with agriculture and the need to focus on developing aquaculture based on herbivorous or at least omnivorous fish. In this way, we can create new food using a high percentage of agricultural products, including agricultural waste. Rashid stated that while there is room for aquaculture to grow, he feels people are overly optimistic on what it can do, particularly as it is highly concentrated in China and Asia. He stressed that distribution and social dimensions are key considerations, for example, people in the Pacific islands will not easily be able to get fish from China. Weatherdon shared that they are focusing on integrated development to avoid replacement of one production system by another. She cited shrimp farming usurping mangroves, and the important trade-off that takes place when that happens. The economic losses in ecosystem services, while not always immediately apparent, are serious and must be considered. She suggested looking at highly localized and community-based approaches, using local species. Gutiérrez shared Peru's experience, noting that most of their production goes to fish meal or fish oil production, not to the people in the highlands. He suggested diversifying this approach as well as getting more fish to local populations. Rice also noted that if we are going to meet future food need, and this 100 million tons of food cannot come from agriculture, then we must change our expectation for types of fish and risk tolerance. He underlined that there will be many uncomfortable conversations that must be had.

Bell then asked Rice, with his extensive experience in marine spatial planning, to expand on this idea and asked where he expects this dialogue to go to minimize the compromises for biodiversity. Rice expressed some optimism by noting that, for the first time, he is part of an intergovernmental policy discussion founded on the fact that human wellbeing depends on a wide range of ecosystem services. He expressed that only recently have we begun to discuss the number of ecosystem services that have been lost by increasing agricultural production. We need to examine the development of coastal ecosystems to ensure that we plan sufficiently for the inevitable need to balance the various necessary uses of coastal waters, and be sure not to go down the same path that occurred for land use.

Session IV: Wrap-up, Panel Discussion and Closing Ceremony

34. The Panel Discussion and Wrap-Up Session on September 18 commenced at 09:00. The session was chaired by Dr. Mark Howden from Australian National University.

    Session I: Dr. Alexander Ruane spoke about each of the presentations in his session, highlighting key elements of each. He then discussed the common themes and messages, noting that the availability, access, utilization, and stability of food supply are all important for food security and must be factored into risk management. He explained that improving forecasts help us understand threat from weather extremes today and the way that extremes change with the global climate, and that the impacts from subtle changes may be as important as headline events. He highlighted remote sensing and on-the-ground observations to monitor agricultural status. Ruane noted that crop models, when calibrated and tested, provide agricultural outlooks that may be used to determine recommended practices and policy strategies He noted that speakers also underlined the usefulness of decision support systems in assisting farmers to build robust climate-smart strategies, which often require persistence across interannual extremes. Finally he highlighted that indigenous knowledge underscores the need for a diverse portfolio of approaches. Ruane then outlined some connections to other sessions, though noted that there are some interesting links to agroforestry that were not explored in the symposium. He stressed that climate change impacts may be most prominent through extreme events embedded within average climate trends and that these need to be factored into climate change projections. Extreme events require the consideration of resilience and behavior beyond the standard equilibrium approaches. He noted that models can help us characterize the costs and benefits of various approaches to development and adaptation, while the virtual identification and prioritization of development priorities and adaptation strategies is an important step in practical and resource-limited decision making. Finally Ruane underlined the fact that we are likely to see increasing interaction between agriculture and fisheries in supply of food, but also in demand for resources. Howden then followed up by highlighting the multiple dimensions of the issue, that we can learn from the operational delivery of the information we have, and that we need to focus on the contextual nature of the response, for example by integrating local knowledge. Finally he stressed the need to recognize that information is needed right now and will be needed even more in the future.

35. **Session II:** Dr. Maximo Torero spoke about each of the presentation in turn, He then discussed common themes. He stressed that in addition to looking at yield, we need to look at demand. He felt that we need to think more carefully about what support the government is giving to various crops. He explained that staples, which are projected to be some of the least vulnerable, are funded while more vulnerable crops are ignored. Torero highlighted the importance of bringing climate, social, and economic models together, in building an enabling policy environment, building capacity, and giving

information in an appropriate manner. He stressed that we need to think about farmers and their needs, in addition to the improvement of risk insurance. He argued that there is an essential need in shifting from a single target to multi-target policies to suit the multi-dimensional nature of food security, and spoke about the importance of data. Howden then followed up with some key messages. He explained that we will have to expand our approach in the four aspects of food security towards the whole range of sustainable development goals. To do this, he explained that finding what is important for vulnerable groups, including prices, nutrition and variability, is critical. He argued that we cannot afford to ignore the implication of integrated market development and prices on these vulnerable groups. Howden brought up the trend in Session II to explore practical ways to improve livelihoods, which included insurance informed relocation, crop calendars, integrated market development, supply and demand, and infrastructure. Finally, he stressed the importance of good evaluation, so that we can learn what is working, why, and how to do it better.

36. **Session III:** Dr. Johann Bell took a different approach, synthesizing key messages from the six speakers. Noting the importance of fisheries to food and nutritional security, he reiterated the huge future demand for fish – with a projected need for an additional 75 million tonnes of fish by 2050. He explained that most of this population growth will be seen in developing countries that are vulnerable to food insecurity. He expressed optimism for meeting this goal due to improvements to aquaculture and better management of fisheries and fish habitats, and mentioned that there may be some scope in increasing catch potential but this must be approached carefully. However, he then outlined the various impacts of climate change on the oceans, listing issues such as lower oxygen levels, redistribution of biodiversity, and sea surface temperature warming causing the stratification of the water column, impeding the upwelling of nutrients which underpin fisheries production. The implications of this are significant, with a range of winners and losers within economies, and our current model biases revealing uncertainties indicate that caution is needed. He encouraged the investigation of how climactic variability is impacting fish production so that we can learn from responses of fish populations. Bell then discussed key adaptation measures, such as flexible management and balanced harvests, where species are harvested in proportion to their abundance. This maintains ecosystems and avoids trophic cascade effects but requires changes in eating habits. Bell noted that we need to examine trade patterns, posing the questions: is revenue from fish exports better for food security than keeping the fish in the country? He raised a number of issues for governance and aquaculture, such as transboundary management as stocks migrate across exclusive economic zones. Finally, Bell examined the promise of agriculture, stating that it could provide the additional fish required but detailed some serious concerns including the impact of climate change on disease incidence and virulence, the impacts on local environments and wild fisheries, and the limits to expansion. He then listed some future directions, including the greater use of herbivorous and omnivorous species, increased reliance on agricultural products and waste products for feeds, expansion of small pond aquaculture, and integration with agriculture. Finally, he stressed that an integral part

of marine spatial planning must be to reconcile food security with the conservation of biodiversity.

37. Howden followed up with his own summary, stressing that the sustainable production of fisheries is tightly linked to environmental management: Particularly in fisheries, both wild caught and aquaculture, there is a very strong link between environmental management and productivity. He suggested we pursue sophisticated and flexible institutional responses informed by science as well informed and flexible management is the key to the future.

38. **Panel Discussion: Dr. Mark Howden (Australian National University) , Dr. Heekyung Park (Korea Advanced Institute of Science and Technology), Prof. Elwynn Taylor (Iowa State University), Dr. Maximo Torero (IFPRI), Dr. Dimitri Gutiérrez (IMARPE), Dr. Waldo Lavado (SENAMHI)**

Howden began the panel by asking panellists to introduce themselves and explain how this relates to their work. Lavado explained that he works as a hydrologist in SENAMHI, and linked hydrometeorolgical data to crop models. He shared some difficulties that SENAMHI faces in trying to obtain this data, such as working in jungles, but noted that they need to improve the spatial resolution. He explained that they produce a lot of information but need to ensure that users actually employ this information. SENAMHI wants to improve their relationship with decision makers and improve seasonal forecasting. Lavado also explained that SENAMHI is also researching food security and climate variability change. Torero explained the two major dimensions of his job – linking farmers to markets and policy-centred work. As one of the only policy centres in CIAR his group focuses on the market aspect. The second level, he explained, is at the global level, which is mostly done through conferences like APEC but also through the UNFCCC COP and other bodies, as they want to influence how key topics are being addressed. He stressed their focus on data, that data should be a public good, and that they look at weather, crop calendars, and prices, among others. Data has a large commercial value and the government needs to be involved. Park underlined the importance of not just having tools but using them properly, stating that being “smart” means being wiser. Taylor explained his background in botany and focus on education, saying that we have learned a lot about the environment and now appreciate that we need to adapt. Gutiérrez explained the Ocean Institute of Peru’s central mission is to perform research to help decision-makers in managing fisheries, but also for biodiversity and the preparation for and management of extreme climactic events. He explained that this is a very big task as climate variability is the main driver of the carrying capacity of the fisheries in Peru, which includes ENSO but also decadal variability and now climate change. So, in addition to the scientific complexity of dealing with the non-linear responses between climate and environment, they are also addressing societal impacts. Gutiérrez then shared lessons they have learned about how society responded, in addition to government and institutions, to the anchovy crashes to illustrate their experiences. Howden explained that a central part of his job is to link

researchers, policy-makers, and communities. He believes that climate-smart information is actionable information and that we are moving on the spectrum of action and information towards action. He explained that though we have seen a massive improvement in our capacity to transfer data, citing the difference in bandwidth over a decade, but argued that we have improved only marginally in our ability to transfer information.

Dr. Ken Takahashi then asked about decadal variability, noting that this can have a large impact due to its long-term effect. He said that this might be the most immediate threat in terms of food security, but has not yet been addressed explicitly in these presentations. Howden noted that looking back, we are understanding how inadequate a 100-200 year window on climate data is. The key message is that we need caution in assuming we know how to optimize our systems, such as the economy, in the face of varying degrees of variability, even without the challenge of climate change.

Alicia Ilaga from the Philippines asked what the key messages were to be brought back to their ministers and put into action. Gutiérrez brought up the three aspects to focus on that have been discussed on the fisheries side i) the food security demand, which exists without climate change, ii) increasing vulnerability of fish resources, exacerbated by climate change, and iii) the importance of addressing local regional realities. Torero had five recommendations i) improve efficiency and reduce losses, ii) gather tools to increase resilience, and be careful to understand variability and risk iii) recognize the importance of the relationship between supply and demand, as there is often an exclusionary focus on the former, iv) that instruments and data need to be available and public, as well as supporting an increase in funding for research on agriculture that will allow for innovations, and v) he urged governments to bring together ministries of agriculture and finance, stressing the importance of such a dialogue. Park highlighted the importance of making many small success stories. Taylor stressed the importance of the variations in drought.

Dr. Hong-Sang Jung inquired how we can move the discussion away from production towards transport, food storage, and other elements, as the climate impacts on these are important. Torero emphatically agreed, noting there is a lot of focus on production. He cited the work of Amartya Sen, and expanding the discussion of food insecurity to include the underlying drivers which are disturbances, conflict, and property rights rather than an actual food shortage. He stressed that the whole value chain is extremely important.

39. Dr. Hong-Sang Jung, the Executive Director of the APEC Climate Center, concluded the symposium with a speech reiterating the key points of the symposium, while thanking everyone for their active participation. Ms. Carmin Azurin, Head of the APEC Directorate in the Ministry of Foreign Affair, then gave a speech thanking the participants, congratulating all on the success of the symposium, and linking the symposium outcomes to the larger APEC goals.

ANNEX: APEC Climate Symposium 2016 Participants List

No.	Economy	Affiliation	Title	Name
1	Australia	Climate Change Institute, Australian National University	Prof.	Mark Howden
2	Australia	Conservation International	Dr.	Johann Bell
3	Australia	Australian Department of Foreign Affairs and Trade	Ms.	Monica van Wensveen
4	Australia	Bureau of Meteorology/Climate Information Services	Dr.	Paul Gregory
5	Brazil	University of Passo Fundo	Dr.	Willingthon Pavan
6	Canada	Marine Programme, UNEP World Conservation Monitoring Centre	Ms.	Lauren Weatherdon
7	Canada	University of British Columbia	Dr.	Rashid Sumaila
8	Canada	Fisheries and Oceans Canada	Dr.	Jake Rice
9	Chile	Food and Agriculture Organization of the UN, Latin America and Caribbean Regional Office (FAO)	Ms.	Laura Mesa
10	Chile	Ministry of Agriculture, Chile	Mr.	Mauro Arias
11	Chile	DIRECCIÓN METEOROLÓGICA DE CHILE	Mr.	Enrique Osvaldo Garrido Segovia
12	China	Chinese Academy of Agricultural Sciences	Dr.	He Yingbin
13	Chinese Taipei	Central Weather Bureau	Dr.	Tien-Chiang Yeh
14	Chinese Taipei	Central Weather Bureau	Dr.	Ming-Ying Lee
15	Columbia	CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)/ International Center for Tropical Agriculture (CIAT)	Dr.	Ana Maria Loboguerrero Rodriguesz
16	Columbia	International Center for Tropical Agriculture (CIAT)	Dr.	Julian-Rameriz Villegas
17	Germany	Alfred Wegener Institut (Biosciences | Integrative Ecophysiology)	Prof	Elvira Poloczanska
18	India	Regional Integrated Multi-hazard Early warning System (RIMES)	Dr.	Govindarajalu Srinivasan
19	Indonesia	Ministry of Marine Affairs and Fisheries (MMAF)	Mr.	Banard Caisaro Purba
20	Indonesia	Senior Researcher for Marine and Fisheries Research Agency	Dr.	Wijopriono Tamin Sastro
21	Indonesia	Ministry of Marine Affairs and Fisheries of Republic of Indonesia	Ms.	Rita Octafiani
22	Indonesia	Meteorological Climatological and Geophysical Agency for Indonesia (BMKG)	Mr.	Marjuki MJ
23	Japan	National Agriculture and Food Research Organization	Dr.	Toshichika Iizumi
24	Korea	International Food Policy Research Institute (Environment and Production Technology Division)	Dr.	Ho-Young Kwon
25	Korea	Pukyong National University/Dept. of Environment & Atmospheric Science	Dr.	Jaiho Oh
26	Korea	APEC Climate Center (APCC)	Dr.	Hongsang Jung
27	Korea	Korea Advanced Institute of Science and Technology	Dr.	Heekyung Park
28	Korea	Korea Maritime and Ocean University	Dr.	Kiwhan Lee
29	Korea	APEC Climate Center (APCC)	Dr.	Jin Ho Yoo
30	Korea	APEC Climate Center (APCC)	Dr.	Kwanghyung Kim

31	Korea	APEC Climate Center (APCC)	Dr.	Taewoo Ryu
32	Korea	APEC Climate Center (APCC)	Dr.	Yonghee Shin
33	Korea	APEC Climate Center (APCC)	Ms.	Sangwon Moon
34	Korea	APEC Climate Center (APCC)	Ms.	Inja Jeon
35	Korea	APEC Climate Center (APCC)	Mr.	Gyeongseok Jo
36	Korea	APEC Climate Center (APCC)	Ms.	Christianne Aikins
37	Malaysia	Malaysian Agriculture Research and Development Institute (MARDI), Ministry of Agriculture and Agro-Based Industry (MOA)	Ms.	Norlida Binti Hamim
38	Malaysia	Sea to Space Division, Ministry of Science, Technology and Innovation (MOSTI)	Mr.	Sivaneswaran Goval Krishnan
39	Mexico	National Weather Service of México	Mrs.	Maria del Carmen Hoechst Velez
40	New Zealand	National Institute of Water & Atmospheric Research Ltd, New Zealand	Dr.	Brett Mullan
41	Peru	SENAMHI	Eng.	Amelia Ysabel Diaz Pablo
42	Peru	Instituto Geofísico del Perú (Geophysical Institute of Peru)	Dr.	Ken Takahashi
43	Peru	International Potato Center	Dr.	Roberto Quiroz
44	Peru	International Food Policy Research Institute	Dr.	Maximo Torero
45	Peru	International Potato Center	Dr.	David Ellis
46	Peru	SENAMHI	Mrs.	Grinia Avalos
47	Peru	Peruvian Marine Research Institure (IMARPE), Department of Oceanography and Climate Change	Dr.	Dimitri Guiterrez
48	Peru	Ministry of Foreign Affairs- APEC Directorate	Mrs.	Carmen Azurin
49	Peru	SENAMHI	Mr.	Waldo Lavado
50	Peru	SENAMHI	Mrs.	Gabriela Rosas
51	Peru	SENAMHI	Mr.	Giann Velasquez
52	Peru	SENAMHI	Mr.	Glicerio Canchari
53	Peru	SENAMHI	Mr.	Hector Yauri
54	Peru	SENAMHI	Mr.	Jorge Carranza
55	Peru	SENAMHI	Ms.	Ninell Dedios
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58	Peru	Ministry of Agriculture and Irrigation	Mr.	Leon Rivera Olivan
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60	Philippines	Department of Agriculture	Dr.	Saturnina Halos
61	Philippines	Department of Agriculture	Ms.	Alicia Ilaga
62	Philippines	Department of Agriculture	Ms.	Angela Velasquez
63	Philippines	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)	Mrs.	Edna Juanillo
64	Philippines	Philippine Atmospheric, Geophysical and Astronomical Services Administration	Dr.	Flaviana Hilario
65	PNG	National Weather Service (PNGMET)	Mr.	Samuel Maiha
66	PNG	Economics and Planning Division at Office of Coastal Fisheries Development Agency	Mr.	Joshua Ryan
67	Russia	Voeikov Main Geophysical Observatory	Dr.	Vladimir M. Kattsov

68	Thailand	Department of Fisheries	Ms.	Jintana Nugranad
69	Thailand	Marine Fisheries Research and Development Division, Department of Fisheries	Mrs.	Piyawan Hussadee
70	Thailand	Department of Fisheries	Dr.	Jutarat Kittiwanich
71	Thailand	Department of Fisheries	Mrs.	Panawon Awaiwanont
72	Thailand	Thai Meteorological Department	Dr.	Songkran Agsorn
73	USA	Iowa State University	Dr.	Elwynn Taylor
74	USA	NASA Goddard Institute for Space Studies (Climate Impacts Group)	Dr.	Alexander Ruane
75	USA	Naval Postgraduate School	Prof.	Chih-Pei Chang
76	USA	US Department of Agriculture Climate Change Program Office	Dr.	Margaret Walsh
77	USA	US Department of Agriculture /FAS	Mr.	Manuel Oliva
78	USA	US Department of Agriculture, Foreign Agricultural Service	Mr.	Micah Rosenblum
79	USA	US Agency for International Development, Regional Development Mission for Asia	Mr.	Kipp Sutton
80	USA	US Department of State	Ms.	Fumiyo Tsuda
81	Vietnam	Ministry of Agriculture and Rural Development	Mr.	Le Thanh Van
82	Vietnam	DOSTE, Ministry of Agriculture and Rural Development	Dr.	Pham Manh Cuong
83	Vietnam	Global Integration and Investment Division, International Cooperation Department, Ministry of Agriculture and Rural Development	Ms.	Dinh Thi Thanh Huyen
84	Vietnam	Science, Technology And International Cooperation Department, National Hydro-Meteorological Service, Viet Nam	Dr.	Thai Hung Dinh