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Information Bulletin

Climate Change

What is climate change?

Climate change presents a potentially devastating threat to humans and many other species on Earth. Surviving this threat requires immediate and long-term efforts to mitigate and adapt to the effects of climate change. Innovations in genomics promise to contribute to both mitigation and adaptation.

Since the industrial revolution, human activity has resulted in large-scale emissions of greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide, ozone, hydrofluorocarbon) which have precipitated large increases in atmospheric concentrations of these gases. Greenhouse gases trap heat in the atmosphere and contribute to rising global temperatures. Rising atmospheric temperatures can have widespread effects on the global climate, including: warmer temperatures at the earth's surface and in the oceans; changing wind patterns; and an increase in the frequency and severity of extreme weather events (e.g., heat waves, heavy precipitation, drought).

The effects of climate change are already observable and include: loss of ice sheets, sea ice, glaciers, and permafrost; rising sea levels; acidification of the oceans resulting from oceanic uptake of carbon dioxide; degradation of the quantity and quality of water resources in some regions; and changes in animal and plant behaviours (e.g., hibernation periods are shortening, fish are moving further north, trees are budding and plants are flowering earlier in spring).

The Intergovernmental Panel on Climate Change (the international body for assessing the science related to climate change) has concluded that: "Limiting climate change would require substantial and sustained reductions in greenhouse gases which, together with adaptation, can limit climate change risks."

How can genomics contribute to climate change mitigation?

Climate change mitigation involves efforts to reduce or eliminate greenhouse gas emissions and efforts to remove greenhouse gases from the atmosphere. Carbon sequestration, the process of capturing and storing atmospheric carbon dioxide, is one of the key tools for mitigating climate change. Natural biological processes, such as plant growth, capture atmospheric carbon dioxide. Genomics can contribute to climate change mitigation by maximizing the carbon capture and storage effects of natural biological processes.

For example, wetlands restoration is a promising strategy for climate change mitigation. Coastal wetlands store more carbon per unit area than other ecosystems. They capture large amounts of atmospheric carbon through rapid annual tree and plant growth. Within the largely oxygen-free wetland soils, carbon decomposes very slowly and is stored for hundreds to thousands of years. Coastal wetlands offer a number of additional benefits, including: protecting and improving water quality; providing fish and wildlife habitats; storing floodwaters and maintaining surface water flow during dry periods. Under certain conditions, however, wetlands can also produce massive amounts of methane—a greenhouse gas—which is where genomics can play a role. Researchers have begun using genomic sequencing, along with biogeochemical methods, to explore the diverse microorganisms involved in methane production and consumption and to develop wetlands management strategies to reduce methane emissions and to enhance carbon sequestration.

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Livestock farming contributes 18% of global greenhouse gas emissions, and 35% of those emissions consist of the methane that ruminants (e.g., cattle, goats, sheep) produce while digesting plants. Methane emissions depend partly on the characteristics of the feed consumed by ruminants, but individual differences produce variation in methane emissions across animals. Genomics researchers are working to develop methane emission mitigation strategies by increasing the efficiency of ruminant digestive systems. There are two aspects to this work: (1) finding the genetic markers in ruminants that affect methane emissions; and (2) genome sequencing of methane-producing microbes in ruminants digestive tracts. Breeding ruminants with more efficient digestive systems is expected to carry two benefits: the animals will produce less methane and will require less feed to produce the same amount of milk or meat.

Agroforestry is another promising strategy for climate change mitigation. Trees capture atmospheric carbon through photosynthesis and store it in their branches, trunks, leaves and roots. Agroforestry is an integrated approach to sustainable land use that purposefully integrates the growing of trees with crops or livestock. In addition to capturing and storing atmospheric carbon, trees confer a number of additional benefits: they stabilize the soil to prevent erosion; they raise water infiltration rates, which limits surface flow during rainy seasons and increases ground water release during dry seasons; they also improve the soil by preventing nutrient leaching, fixing nitrogen, and contributing organic matter. Genomics can contribute to maximizing the potential of agroforestry. For example, selection based on genomic data, coupled with innovations that shorten the time it takes to complete the tree breeding cycle, can support agroforestry practices that maximize yield while mitigating climate change.

Agroforestry products (e.g., edible fruits and nuts, food and cosmetic oils, timber, wood biomass for conversion into biofuel) can improve the livelihoods of small-scale farmers considerably. Genomics also has a role to play in the utilization of agroforestry products. For example, poplar trees are often planted in agroforestry systems: they grow quickly, provide excellent windbreak, can be intercropped with a wide variety of commonly planted crops, and they produce large amounts of biomass that can be converted into biofuels. However, producing biofuel from poplars is impeded by the lignin component of wood, which must be broken down to release the energy-rich sugars. The process of breaking down lignin requires energy, which increases the cost and decreases the efficiency of biofuel. Recently, researchers have genetically engineered a hybrid poplar in which the lignin breaks down more readily. This results in a nearly 50% increase in biofuel yield without affecting the growth or biomass production of the trees.

How can genomics contribute to climate change adaptation?

Even if large scale efforts to mitigate climate change are implemented very soon, some degree of climate change will very likely continue over the next several decades, and humans and ecosystems will need to adapt to a new global climate.

Climate change presents a major threat to food security. As the human population grows, the demand for food crops is rising. Simultaneously, climate change is impeding productivity increases. Extreme weather events, especially floods and droughts damage crops and reduce yields, and warmer weather can inhibit productivity in a variety of ways. For example: high nighttime temperatures can decrease crop yields; warm winters cause premature budding and subsequent crop failures; high summer temperatures cause soils to become drier and exacerbate the effects of droughts. As well, many weeds, pests and fungi thrive in warmer temperatures.

Previous increases in productivity have been achieved through the use of fertilizers and pesticides, but these methods cannot sustain continued increases in productivity. Genomics offers tools to meet the challenge of increasing food production in the context of climate change. For example, genomics-assisted breeding can contribute to sustainable increases in food production by adapting current crops to climate change induced stresses and by breeding novel crop varieties.

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Climate change also threatens the world's forests. In California's ongoing drought, 102 million trees have died since 2010, with 62 million tree deaths in 2016 alone. In general, trees are well adapted to their local climates, but as climate change modifies some local climates, existing trees in those locations are no longer genetically equipped to thrive. To address this problem, researchers are using new phenotyping and genomic methods to inform the selection of trees to facilitate rapid adaptation to climate change.

Other researchers are studying tree microbiomes, the microorganisms that live symbiotically with trees. Certain types of fungi are key players supporting the growth, health and stress tolerance of forest trees. Researchers have identified specific traits in the transcriptome of C. geophilum—the most common type of fungus that lives symbiotically in the root systems of forest trees—that can help their hosts be more resistant to drought stress. These findings can lead to the selection of more drought-resistant trees.

What are the next steps for genomics and climate change?

Much of the genomics-based climate change arsenal is still in the research and development phase. Further work, both at the level of basic research and of translation, is required to realize the potential for genomics to contribute significantly to climate change mitigation and adaptation.

More Information and Resources

https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

http://climateactionnetwork.ca/issues/what-is-climate-change/

http://www.climatechangegenomics.org/white_paper.php

http://sdg.iisd.org/news/world-bank-releases-report-on-mitigating-climate-change-through-wetlands-restoration/

https://www.genomecanada.ca/en/increasing-feed-efficiency-and-reducing-methane-emissions-through-genomics-new-promising-goal

http://www.sciencedirect.com/science/article/pii/S1877343513001255

http://www.nature.com/articles/ncomms11989

https://www.genomecanada.ca/en/resilient-forests-res-climate-pests-policy-genomic-applications

http://jgi.doe.gov/cenococcum-help-trees-tolerate-drought/

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