A BIOMASS FUTURE FOR THE NORTH AMERICAN GREAT PLAINS

ADVANCES IN GLOBAL CHANGE RESEARCH

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A BIOMASS FUTURE FOR THE NORTH AMERICAN GREAT PLAINS

Toward Sustainable Land Use and Mitigation of Greenhouse Warming

by

Norman J. Rosenberg

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This book is dedicated to
Joshua, Rachel, Ariella,
Daniel, Alyssa, and Bettina
and, of course to Sarah

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PREFACE

WHY THIS BOOK?

This book is an exploration of the possibility that a significant portion of the North American Great Plains (NAGP), now primarily in rangeland, corn, soybean, and small-grain production, can be converted to the production of biomass-energy crops. Biomass can be used as a substitute for some of the fossil fuels the use of which is now increasing the atmospheric concentration of carbon dioxide (CO_2) and contributing to global warming and climatic change. Such a land use change to biomass could lead not only to a global good but also to specific economic and environmental benefits for the NAGP region. This analysis is prompted by the following facts and trends:

> The emission of CO_2 from fossil fuel combustion and tropical deforestation and the rising concentrations of other greenhouse gases make global warming a virtual certainty in this century; indeed the evidence is strong that a warming is already discernible.
>
> Global warming will lead to climatic change and, while the geographic distribution of this change is not yet known, most general circulation models (GCMs) suggest that midcontinental regions in the northern hemisphere (such as the NAGP) are likely to become drier as well as warmer.
>
> NAGP, one of the world's major breadbaskets, is subject to periodic droughts and other climatic stresses that may worsen with global warming. Thus, it is prudent, if only for their own benefit, that the people and governments in this region seek ways of reducing the emissions of greenhouse gases.
>
> Among climate change mitigation strategies now under consideration are the expansion of nuclear power production, capture of fossil fuel carbon at the smokestack and its transport to and sequestration in geologic strata and the oceans, afforestation, introduction of substantial solar and wind energy infrastructure, sequestration of carbon in soils in the form of organic matter and production of biomass as a substitute for fossil fuels. Each of these options has associated physical, environmental, and economic risks. Soil

carbon sequestration and biomass production are among the most environmentally benign options and are well suited to the NAGP region.

Whether combusted for boiler-fuel or converted to liquid transportation fuels such as ethanol, biomass essentially recycles carbon, withdrawing CO_2 from the atmosphere through photosynthesis and returning it when the vegetation or its derivative products are consumed.

Whereas fossil fuels burden the atmosphere with carbon drawn from ancient geologic storages, biomass recycles carbon and should add little or no additional carbon to the atmosphere. Indeed, if a way can be found to capture the carbon released in biomass combustion or processing and to sequester it (as is actually being done on an experimental scale for coal-fired power plants), biomass could lead to a net "negative emission" of carbon and, perhaps, actually lower the atmospheric concentration of CO_2.

Ethanol is now produced in the NAGP and adjacent regions primarily from the starch in grain corn. Some calculations have shown that the ethanol so produced is nearly energy-neutral, its final energy content being not much greater (perhaps even less) than the energy required to produce it. Recent analyses suggest an energy gain of as much as 25%. For decades now, ethanol production for fuel has been profitable to producers only if directly or indirectly subsidized.

In addition to the use of high-cost grains, it is now feasible to convert the cellulose in corn stover, wheat straw, and all types of biomass to ethanol through the use of enzymes that break the strong bonds between sugar molecules that make up the cellulose structure. New enzymes, genetically engineered for that purpose, will make cellulosic ethanol far more energy efficient and cost competitive than ethanol from grain can ever be. However, $60–70 per barrel (and who knows how much higher the price may go?) petroleum makes even ethanol from grain appear competitive. Production from cellulosic biomass materials should be even more so. Unsubsidized ethanol production from biomass is conceivable.

It has been strongly argued that agriculture as currently practiced in the NAGP is unsustainable. Although soil erosion has been reduced by conservation strategies implemented since the "dirty-thirties," overuse of chemical fertilizers and pesticides and the mining of groundwater resources create serious environmental problems in this as in many other agriculturally intensive regions of the world. For these reasons some scholars have suggested that large portions of the NAGP should be returned to its native vegetation and fauna and that a "Buffalo Commons" replace its farms and ranches.

While the world faces a problem of consequential climatic change, it also faces population pressures and expected improvements in worldwide

> living standards that will increase demand for both energy and agricultural products. Thus, diversion of land to grass or biomass energy production raises the question of how needed food, feed, and fiber will be provided in the future.
>
> Perennial biomass crops such as switchgrass (*Panicum virgatum*) and the poplar (*Populus* spp.) (as well as many other species being studied at this time) require less tillage and fewer pesticide and fertilizer applications and may, thus, be better sustainable than the traditional crops they could replace (as well as being more popular and politically feasible and likely of implementation than the Buffalo Commons). As the roots of crops—particularly perennials—decay, they deposit carbon in the soil, some of which is sequestered for very long periods of time. In addition, conservation tillage practices consistent with sustainable agriculture favor soil carbon sequestration. Such tillage practices require less energy than conventional farming practices and may also favor biodiversity. Biomass crops, which are mostly perennials, should prove better with regard to soil carbon sequestration than traditional annual crops. The culture of biomass crops is consistent with conservation tillage.

Each of the issues and questions posed above are addressed in this book as is the matter of whether ecological, environmental, and economic arguments support the need for a significant conversion of NAGP lands back to grass cover, to biomass cropping, or both. Two other questions addressed: Can genetic modification of biomass crops increase their productivity to the point of economic competitiveness? Can the productivity of traditional (or new) crops be increased sufficiently to compensate for decreases due to conversion of substantial areas of agricultural land to biomass production?

WHY THIS WRITER?

This book is a labor of love. Immediately upon completion of graduate studies in soil physics and meteorology at Rutgers University, I was hired by the University of Nebraska to initiate a program of research in agricultural climatology. The objective of this program was to find ways to diversify Nebraska's agriculture, then (as now) almost entirely devoted to extensive corn, soybean, and wheat production, to enable production of higher per acre value vegetables and industrial crops.

Nebraska has excellent soils and plentiful water resources, but its climate is severe. My job was to find ways to somehow reduce vulnerability of the high-value crops to climatic stresses or to protect these crops from them. My first experiments were aimed to improve understanding of how windbreaks could best be designed to moderate the microclimate of crops grown in their lee. After working for a few years on that problem (with some success) I began to study how the water needs of crops might be minimized by wind shelter, by timing of irrigation, and by modification of the plant's "architecture" (e.g., leaf distribution, leaf color, and light penetration into the plant canopy). In order to do the necessary field experiments I had to adapt existing instruments or develop *de novo* nondestructive methods to measure evapotranspiration and photosynthesis in the field. Hence I gained experience with micrometeorological sensors for measuring the instantaneous exchanges between soil, plant, and atmosphere of heat, momentum, water vapor, and CO_2. Many of these studies were carried out from a laboratory trailer that traveled around the State. But in the mid-1960s I was able to establish a "home-base" at the University of Nebraska Field Laboratory near Mead, Nebraska, on land that had been a part of a recently decommissioned armaments production facility. There my colleagues and I erected a permanent instrument tower for continuous year-round measurements of wind speed and direction, temperature, humidity, and CO_2 concentration.

In 1958, as part of the International Geophysical Year, sensors were placed at the top of Mauna Loa, a 4167 m (13,678 ft.) high volcanic mountain on the "Big Island" of Hawaii to document the changing global concentration of atmospheric CO_2 which was then rising at a rate of ~1 ppmv per annum. Mauna Loa had been chosen for this purpose because its altitude and remoteness from strong local sources and sinks for CO_2 allowed for monitoring a well-mixed atmosphere.

Our observations at Mead, at an altitude of 366 m (1200 ft) in the middle of a vast agricultural region, differed in important ways from those at Mauna Loa. The amplitude of the daily CO_2 concentration wave was far greater at Mead because of the daytime drawdown due to photosynthetic capture of CO_2 by the region's crops and its nocturnal rise due to respiratory release. Similarly, the annual wave had much greater amplitude because of net growing-season capture of CO_2 and its net release during the winter when the vegetation was either dead or dormant. But, the inexorable annual rise in the mean annual concentration was essentially identical at Mead on the eastern Great Plains and Mauna Loa in the central Pacific.

This observation piqued my interest in the entire question of climatic change—an interest that has dominated my career ever since. I began to speculate and write about how climatic change might affect agricultural productivity around the world, but particularly in the USA. I became convinced that there was at least one benefit for agriculture in the rising CO_2 concentration, i.e., that plants would grow bigger and faster because of increased rates of photosynthesis and would use less water in the process because CO_2 induces closure of the stomates (pores) on the leaf through which water vapor exits the plant into the air above. And, although I was convinced from the first principals of thermodynamics that climate must change with continued increase in atmospheric CO_2 concentration, I was skeptical then (and still am to a degree) about how well the regional distribution of changing climatic factors—temperature, precipitation, etc.—could be predicted.

In the late 1970s, I experienced yet another "Nebraska-epiphany" that altered the course of my career. The Great Plains region was struck by another of its very severe droughts in 1977. With others, I was called to the office of the then Governor of Nebraska, J.J. Exon, to advise on what state government should be doing to help the states' farmers and ranchers. I was struck at that meeting by the fact that, despite almost a century of university and agency research on various aspects and facets of drought, there existed no organized plan for dealing with that most inevitable of Great Plains phenomena. It became clear to me that a plan was needed to prepare for and cope with drought and that such a plan must consider not only climatology and agricultural research, but also the societal, economic, political, and even psychological, impacts of drought as well. Having raised the question I was of course charged with setting the process in motion. The outcome of the planning process was *A Drought Strategy for Nebraska*. This concept of drought strategy has been carried forward by others and much more sophisticated and effective plans have by now been developed for most states and many nations as well. But my interest in drought—after death and taxes the third inevitability (at least on the Great Plains) remains strong and has taken me to many other drought-affected regions of the world.

My interest in climate change and drought led in 1987 to a job change. I joined Resources for the Future, a Washington, DC-based "think thank" to develop a climate resources program. A major product of that program was a study of the potential impacts of climatic change on the agriculture, water resources, forests, energy, and overall economy of the central US region comprised of Missouri, Iowa, Nebraska, and Kansas (the MINK study). The research had been funded by the Department of Energy and done in cooperation with the Pacific Northwest National Laboratory. In 1992, I was invited to join Pacific Northwest National Laboratory (PNNL) where I continued to study impacts of climate change on US and world agriculture and water resources.

From the 1970s to this time the evidence has strengthened that mankind is altering the earth's climate through emissions of CO_2 from fossil fuels and other greenhouse gases and by tropical deforestation, burning, and other forms of land use change. By this point, I am fully convinced that anthropogenic climatic change is real and that steps must be taken to reduce the rate of change and, hopefully, reverse its direction.

There is within PNNL a strong program to develop technologies that can contribute to the mitigation of climatic change by finding ways to reduce greenhouse gas emissions and/or to capture and sequester the CO_2 that continues to be emitted. In the final five or so years of my pre-emeritus career at PNNL I participated in that program—termed the Global Technology Strategy Project (GTSP)—and helped in developing an understanding of how two mitigation technologies, both focused on agriculture, might contribute to the overall goal. These technologies are soil carbon sequestration and biomass to substitute, at least partially, for fossil fuels.

This book, then, is a synthesis of my ideas on how climate change might affect the US and Canadian Great Plains, a region that continues to be of great interest to me, and how the Great Plains can contribute to a solution of the climate change problem through the two agriculturally based technologies mentioned above. Again, then, this book is a labor of love—for a region, for the physical and social sciencesas well as scientists with whom I have been privileged to work, for our planet, and for future generations threatened by anthropogenic climate changes whose long-term consequences we may know only after much damage has been done.

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