# Re-Vision of a Western U.S. Irrigation Area: Review of Context and Relevant Factors

John Wiener (john.wiener@colorado.edu) Illustrations: <www.colorado.edu/ibs/eb/wiener/ - illustrations tab

## for Decision Support for Climate-Responsive Urban and Agricultural Water Supply and Demand – David Yates and John Wiener

The support of the National Oceanic and Atmospheric Administration Climate Program Office, Sectoral Applications Program, is gratefully acknowledged, and the support of the remarkably capable staffs at the Research Applications Program of the National Center for Atmospheric Research, and the Institute of Behavioral Science at the University of Colorado. Please also see the dedication.

**Preface:** There are two unusual features of this report. First, it was written without review of the National Research Council's 2010 report, Towards Sustainable Agricultural Systems in the 21st Century, available at no charge from the website of the National Academies Press. The intent was to present a summation of issues and conditions, and then some arguments, based on a series of research efforts focused on Colorado and transfers of agricultural water from irrigation. Various aspects are explored in a series of presentations in Powerpoint ™ posted or urls given at <www.colorado.edu/ibs/eb/wiener/>. Additional presentations from 2012 will be posted.

It was something of a comfort that the National Research Council reached some very similar conclusions, given the superb committee with a broad range of expertise, and something of a discomfort that this picture seems increasingly clear. There is not a huge overlap of citations. The group calls for "transformative change" in U.S. agriculture, in addition to "incremental progress" in improving current farming systems. This report is an effort to support such work.

The second unusual feature is that this is support for the application of the Water Evaluation and Planning modeling tool, created by David Yates and others, which is a planning-purposed modeling tool successfully applied world-wide. It can be used at a wide range of scales with as much detail as desired in space, features of the hydrology and water systems, and time, including climate forecasts as down-scaled and desired, with the ability to trade-off detail and complexity versus literally operating in minutes for live explorations. This report serves other purposes – hence the posting – but is in support of the WEAP application for the Bessemer Ditch, and the rapidly expanding WEAP modeling linked to other modeling by the Hydrology Applications Program of the Research Applications Laboratory at the National Center for Atmospheric Research, Boulder, CO; much of that work has been done for users such as the Colorado Front Range Water Providers, and much is part of the Colorado Headwaters program of the Hydrology Applications Program. The next step for this project is to work with the study area participants to choose scenarios for change in land use, farming, and climate scenarios.

Finally, the references here are as of October 2011, when this was done. Posting was delayed to enable review by some of the people who figure prominently in the story. Illustrations are posted separately now; about 32 photos and a set of Powerpoint ™ slides; not keyed to text yet.

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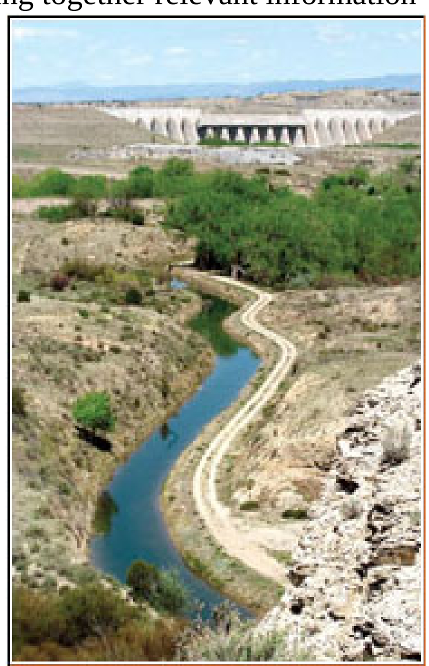
Note: Illustrations are not integrated in this draft; 11 Powerpoint ™ slides and 32 downloadable photos (most are 1.5 mb) are posted at <www.colorado.edu/ibs/eb/wiener/> and a substantial addition on the hydrologic and climatologic modeling for the case study area and Front Range will be added. This draft is for comment.

## Introduction and Background

This report is about more than a project. It is an effort to bring together relevant information affecting the project study area- the Bessemer Ditch agriculture of the Arkansas River Valley, which is influenced by changes and factors from the global to the local, as is common. These changes are seldom considered at the same time, outside of academic writings in some older styles of anthropology and geography. Thus, it is useful to bring these considerations together and attempt to make them useful for the people who are being affected as well as other potential readers.



A reader who wants to understand the motive for this project is urged to start with the section on the Bessemer

Sales. This report is organized in a way that puts that section after a great deal of context, but the Bessemer Sales section is the motivation and the rationale for the rest of the work. The project was funded for far less than the time spent, and was hampered by other problems affecting research timing, but what issues could be more important?

**Dedication:** Hundreds of hours have been donated to this series of projects by people answering questions and explaining local conditions, local history, and how things work in the Valley, outside of hundreds of hours in meetings. Among the most generous, patient, and expert, with the knowledge that some people who should be listed are not, this report is dedicated to Mike Bartolo, Lorenz Sutherland, John Knapp, Jim Valliant, Dan Henrichs, Matt Heimerich, Wayne Whittaker, and Ken Weber. And, among those to be especially thanked are also Richard Rhoades, the staff at the La Junta NRCS office (always helpful, and generous with meeting room), staff at the Lower Arkansas Valley Water Conservancy District, Ross Douthit and the management of the Pueblo County GIS group, Jim Broderick, Bob Hamilton and Phil Reynolds at the Southeastern Colorado Water Conservancy District, and from projects past and seamlessly related to this one, the Arkansas Basin Roundtable, Alan Hamel, and the Water Transfers Guidelines Committee; Steve Jansson; Reagan Waskom, MaryLou Smith, Tim Gates, James Pritchett, Jeff Tranel, Troy Bauder, and Perry Cabot of Colorado State University, and the always informative and thoughtful people of the Central Plains Irrigation Association, both researchers and irrigation equipment dealers. It is a great privilege to work with the agriculture and water communities. This list should be far longer.

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from "Mending Wall" Robert Frost, 1915 (North of Boston; New York: Henry Holt.) ***

*"He moves in darkness as it seems to me,*
*Not of woods only and the shade of trees.*
*He will not go behind his father's saying,*
*And he likes having thought of it so well,*
*He says again, "Good fences make good neighbors."*

## Good News, Bad News:

The headline for this report might be: "Water management study will be window into defining sustainability changes and problems at the local, regional, and national scales". The project has met some important goals but we have been delayed in getting to the interaction and decision support that is now possible using the work done. The modeling tool (the Water Evaluation and Planning tool, WEAP) has been shown to be excellent for this purpose, in applications here and around the world. It is "all dressed up and ready to go" for the study area for this project, which is the Bessemer Ditch as the selected case study in the Lower Arkansas Valley. Using non-intrusive, public data, to specify the crops and farming on this 20,000 acre study area, we have developed localized scenarios for climate-responsive agriculture-urban water management partnerships which can contribute toward creation of a far more sustainable future for this place. The long-term goal being stabilization and conservation of

**Figure 1. The Bessemer Ditch as it leaves Pueblo Reservoir.**

agricultural production capacity, increased value, and increased resilience to climate variation. The climatology and hydrology applied are state-of-the-science, based on modeling and research from the National Center for Atmospheric Research, and developed with support from a number of agencies and water providers and adapted to support this case study. The good news is that there is increasing recognition of the need to address many problems at once to achieve climate-responsive water management for agriculture-urban cooperative supply.

The bad news includes the disaster of the Listeria outbreak, which began last summer and continues to make headlines. At the time of this writing, 28 deaths have been attributed to the signature product from the study area, with many more cases of illness. The people who have steadfastly supported the project, and previous projects, have been badly overtasked with response to this situation as well as fiscal pressures and other stresses. There are also some very important "good news, bad news" interactions with other events in the Valley, and the Bessemer Ditch in particular. Below, these issues are described.

## An Evolving Vision of the Problem

This project has evolved substantially, in the goals and purposes pursued, though the technical modeling proposed and developed has been fulfilled in a surprisingly valuable fashion. The original goal was to advance a series of projects on increasing the use of climate information in water management in the focal area, to develop more desirable and more climate-responsive agriculture-urban water transfers. Earlier projects have considered the use of climate information in the development of partnerships between urban water systems and irrigators, and this project was intended to more closely model climate-responsive arrangements which would take the discussion farther than before. The essential progress sought was to use WEAP as a planning-purposed model to support a process in which parties could quickly evaluate alternatives. There are important changes in the discourse which has led to both delays in the process we are seeking to support, and a fruitful series of reconsiderations of what is at risk, the scope of the changes needed, and the way forward. There is also an important local history which has affected the project, and that will be noted after the contextual changes are sketched.

Climate change adds to the stress already creating "bifurcation" of western U.S. farms and ranches into a large number of small farms being supported by the family and a very small number of huge operations owned or controlled by non-national corporations and the call has gone out from the National Research Council for "*voluntary, autonomous adaptation to climate change*". This sort of adaptation leads to ancillary question: Will autonomous adaption lead to optimal outcomes? If adaptation is already occurring, then the preponderance of evidence does not support optimal outcomes. The loss of basic agricultural capacity is already tragic, as land conversion to non-agricultural uses suggest a race between the rising interests in local food, sustainability, ecosystem services, amenity and recreational values, and rapidly changing economics of fuel and dispersed growth, versus the severe pressure for agricultural water transfer, global competition for commodity production and importation of human foods, decreasing profitability for many farmers, aging farmers, soil degradation, and increasing dependence on off-farm and imported inputs to and from global markets. Meanwhile, back on the ranch, more rural areas face perforation from rural residential development with disproportionate ecological impacts, and indirect impacts of changes in feed prices as well as price squeezes from oligarchic markets in inputs and outputs. These lead to changes in regional feed production, often supported by irrigation, but faces pressure to urban water transfer and price squeezes as well. The input-technology-intensification treadmill is set to ramp up even faster with calls to feed the world through higher production and exports.

Any credible vision of resilient, flexible, and more sustainable management of agricultural capacity and decent livelihoods for agricultural families stewarding these private resources and much of the public land, revolves around the ability to resist these market pressures and current valuations and mis-valuations of resources and externalities. To some extent, the markets are gradually registering externalities, ecosystem services, public and long-term interests in some marginal ways. Some regulatory actions reflect increasing interest in water quality and perhaps non-point-source pollution and its impacts. But overwhelmingly, the market deals in private property and the agricultural capacity is in private property. The questions then may center on what resources should be more valuable and therefore ideally better managed in the market, and what resources might be owned differently to provide long-term security for owners that can support transition toward more sustainability?

Helping small agricultural operations retain basic agricultural capacity may be critical to future capacity for resilient and sustainable production as consolidated large operations appear to have undertaken hyper-intensification, market concentration, and specialization with increased and standardized commodity production as the management goal, with unclear results in impacts on soil, basic agricultural capacity, dependence on inputs and imports, ecological impacts and ecosystem services, and long-term orientation. Presently, a small number of very large operations produce a great majority of sales, and take a large majority of commodity payments, while the large number of small farms and ranches produce a very small share of sales dollars and are involved in the large majority of rental conservation programs such as the Conservation Reserve Program, by which conservation behavior is rented by the U.S. government on a limited basis. Much smaller programs sometimes pay for permanent or long-lasting conservation infrastructure (e.g. the EQIP program administered by the USDA Natural Resources Conservation Service), but the majority is temporary and subject to reversal when elicited by the markets (as shown in the turn to corn stimulated by the ethanol subsidy payments). The other feature of the huge number of small and commercially very small farms is that they are in the mixing zones where many forms of urban, suburban, and peri-urban land conversions are taking place.

Two kinds of possible future change are particularly notable. One is the call for ecological integration and reduction of simple, mono-culture agricultural systems for the benefit of basic capacity sustainability. One excellent example is work on integrating prairie landscapes with farming in Iowa, by the Iowa State University, John Martin National Wildlife Refuge, and allies (Jarchow et al. 2011, http://www.leopold.iastate.edu/ accessed Dec 1 2011). The other call is for not only managing agricultural lands for environmental quality (Schnepf and Cox Eds., 2007, Schnepf Ed. 2010) and managing at landscape scales (Sassenrath et al. 2010), but also integration of agricultural enterprises on a regional basis to provide synergies in resource uses, make loops of resource flows instead of one-way flows, and increase flexibility and responsiveness of management of the regional resources (Hanson et al., 2008 Renewable Agriculture and Food Systems Spec Section, Vol. 23 No. 4 is a cumulative examination of why and how).

Against such calls, however, are the market structures and seriously concentrated market power in all segments of the food and value chains in and increasingly outside the U.S. (Hendrickson and Heffernan 2007, McIntyre Ed. 2009, Ranchers-Cattlemen Action Legal Fund 2010, U.K. 2011, Lee et al. 2011). This a nearly vertical playing field in major commodities.

We believe there are at least four other obstacles which must be overcome. First, there is the willingness of the agricultural producers to think about the long term and their own perceptions and myths of “the way things are” and “realistically….” how things will be. Second, there are financial and institutional constraints which are difficult to overcome for individuals, including the very short-term financial incentives in current operational and acquisitional lending. Third, there is a lack of organization on local and regional levels which facilitates individual failure, and supports the myths of individualism and fatalism. Fourth, there is a problem in evaluating change, where our skills lie in the economics of changing one thing at a time in a general equilibrium sense. Adaptation to the set of stresses and the increasing additional rates of change in energy, energy-intensive inputs, transportation, consumer preferences, and climate change may require adoption of sets of complementary and interdependent changes. Problematically, these might not appear to be individually rational, but as sets they might lead to more sustainable uses of local and regional resources and more flexibility.

The biggest obstacle to real change may be the need for complementary and interdependent changes, which would be uneconomic if made individually but may be beneficial if made together, are simply quite difficult to think about in traditional agricultural terms. A crude analogy might be re-modeling the bathroom in a house: once you start changing the plumbing you realize that you have to replace some of the floor and to do that you have to take out the other fixtures and when you replace this, you have to change that… and the idea of a decent bath-tub grows into a whole set of parts that are involved and greater time and expense than was hoped. To achieve more sustainable agriculture, including climate-responsive, flexible water management, it may be best to change many problematic aspects… and thinking about the many changes that would be involved is, on the one hand, exactly why we believe so strongly in the kind of planning-purposed modeling that was created for this project. And on the other hand, the project has shown that it is going to be a much larger project to develop all the information that people want to be able to usefully work with a whole set of interdependent changes. Before that re-modeling project is started, what are all those things likely to cost? It is easy to find out the range of costs of the different fixtures and the reasonable bounds on the cost of flooring, sub-floor, some joists, and maybe new water lines, and some foundational shoring if that turns out to be needed – because all those parts and activities are within the near term, working markets, and discoverable costs for finance and labor and materials. But planning for what will work to transition to a multi-functional, multi-enterprise set of resource-conserving activities a few decades away, after “peak water”, peak oil, and increased climate variation and change? On the one hand, there is literature and experience with long-range planning, and it is not easy and takes far more than good hydro-climatology modeling. We did not get there yet. On the other hand, what could be more important than taking the future of our farms and farm families more seriously than hoping that practically irreversible changes and losses will somehow be stopped by the forces that are now so strongly pushing them in the wrong direction?

## *SUMMARY OF WHAT FOLLOWS*

There are six major contextual changes which have formed the discourse in which this project is situated, most of which have taken place on both international and U.S. scales. Four are somewhat specific to Colorado, but we add that Colorado is facing physical challenges which are not unique, though Colorado’s institutional and water law setting is uniquely formalized (Corbridge and Rice 1999). Each of these changes requires explanation, and the bulk of this report is organized as a series of small essays which are intended to explain the issue and how it relates to the project and the direction needed now. Each of these topics has substantial literature, and the reviews are tips of the icebergs. The essays are not an effort to comprehensively review the subjects, and indeed the NOAA SARP staff is well versed in many of the issues and current science of present and changing water scarcity (Climate Change Science Program 2008e Synthesis and Assessment Product 5.3, Intergovernmental Panel on Climate Changes 2008, Cayan et al. 2010 and recent special section in Vol 107 No. 50 of Proceedings of the National Academy of Sciences). What follows is a story that describes a lack of sustainability of much of the agriculture involved in the study area, Colorado, and the U.S. “Fixing” the water problem is necessary but not sufficient, and while the goal of improved and climate-responsive water management is tactical; the strategic goal is stabilizing and conserving if not increasing agricultural capacity for the long-term. Readers may also wish to consider the issues raised here as they are treated in the National Research Council’s 2010 report, Towards Sustainable Agricultural Systems in the 21st Century; a few notes on that are appended at the end of this report.

## The Big Picture: Agricultural Sustainability and the Bessemer Case Study

The Bessemer Ditch case study and the Lower Arkansas Valley are affected by international as well as national scale forces that are generally adverse to long-term agricultural sustainability. The relevance to this project is essentially that this context may provide occasional short-term benefits, such as the present high prices for commodity feed and food, but the long-term is not at all cheerful. We mention a few aspects and cite substantial literature because literally global and national problems set the context and create pressure. The largest factor is population growth and the challenge of feeding 9 billion people, as it is often put (Godfray et al. 2010). There is already very serious hunger problems for more than a billion people (Ash et al. 2010), and increasingly concentrated control of international food markets and chains of distribution (McIntyre Ed. 2009; U.K. 2011), so the “fencerow to fencerow” idea has returned; there are starving people and exports help the trade balance, so let the markets be unfettered (Halweil 2004). But it is not clear that “business as usual, only more so” was not deeply involved in creation of the problems rather than solutions (McIntyre Ed. 2009, U.K. 2011).

Historically, with some harsh learning, farmers and ranchers in the region developed fairly effective adaptations to the formerly more stable climate (National Research Council 2010, Warrick 1983), usually based on crop rotations (sequences) which supported self-fueling (animal traction and transport), soil conservation more or less, and low-input sustainable farming with local and regional consumption. But things changed, including agriculture, transportation, fossil energy, and the drive to replace labor with equipment. Field sizes changed, monocultures dominated huge landscapes, and inputs and outputs exploded. And then urban populations boomed and then the climate changed… Now, as the International Assessment of Agricultural Science, Technology and Development (IAASTD 2009) puts it, agriculture is at a crossroads. Climate, water, and agricultural transition are the subjects of this story.

After setting the dismal global scene, three bright spots will be reviewed, and the reasons for calling this a point of leverage will be explained in detail. The overview is that there will or will not be economically viable climate-responsive integrated water resource management in the rather near future, or effectively irreversible losses of productive capacity are likely with severe regional impacts at the least.

## *Feeding the world at what cost or sustaining productive capacity?*

The global and national context for agriculture and agricultural water problems in the U.S. is not cheerful, and it is worth the space in this proposal to mention a few aspects and cite a little of the recent literature because there are two general reactions to this picture. First, considerably more in line with agribusiness and some policy, is the idea that, "we have to feed the world", and therefore must intensify production at any cost, as a moral obligation (and a great opportunity to increase exports; De Schutter, the U.N. Special Rapporteur on the right to food, and Vanloqueren summarize the dominant, conventional views, 2011). The recent spikes in world food prices show increasing vulnerability of the current food system on the global scale (U.K. 2011, IAASTD 2009, World Bank 2008, and see <www.grain.org>). "The food crisis is here to stay." (DeSchutter and Vanloqueren 2011:33). Perhaps because the U.S. is relatively wealthy, even with increasingly energy intensive food systems (Canning 2010) and lengthening food distribution chains (Canning 2011, Lee et al. 2011, Wainio et al. 2011, Godfray et al. 2010), the politics of the Farm Bill seems to attract more attention than underlying problems (Ray 2011). The second reaction is that we badly need changes.

Beyond the well-known issues, U.S. national issues include a radically changing set of farm characteristics (Hoppe and Banker 2010) with important consequences for the resilience and adaptation goals NOAA and others pursue. The "small" farms, as defined by the U.S. Department of Agriculture, share of sales fell by 1/3 between 1993 and 2003 alone, so that most recent data show that these farms owned 63% of the private land in agriculture, but produced only 16% of sales. (The 84% of sales came from often far more intensified very large operations which are only 12% of the number of "farms" per se.) This disparity is mirrored, unfortunately, by the that more than 3/4 of conservation payments from the U.S. are to the small farms, while the very large ones receive the great majority of commodity production supporting and other payments, and 61% of farms received no federal payments at all (Hoppe and Banker 2010). Conservation is not at all evenly distributed, and one may doubt that highly-mechanized highly input-intensive fossil-fuel intensive agribusiness will change course toward more sustainable activities (De Schutter and Vanloqueren 2011, U.K. 2011, IAASTD 2009, World Bank 2008). Small farms using irrigation water in the West face a wide range of stresses with little or no technical support for "voluntary adaptation" to climate change.

There is ample and authoritative information on the challenges of water supply, worldwide (Gleick and Palaniappan 2010, IPCC 2008) and in particular for the U.S. West (Bureau of Reclamation 2011, Pederson et al. 2011) with both increasing competition for water (MacDonald et al. 2011), and changing and less easily usable sources (Cayan et al. 2010, Sabo et al. 2010, Seager and Vecchi 2010, Hughes and Diaz 2008), adversely affecting an already unsustainable situation stressing every major aquatic ecosystem as well as human uses (Gleick 2010). Climate change also aggravates agricultural problems on the international scale of global food insecurity (Hertl 2011, Lambin and Meyfroidt 2011, United Kingdom 2011, Ash et al. 2010, Herrerro et al. 2010, Godfray et al. 2010, IAASTD 2009, World Bank 2008) through impacts on all elements of productive capacity (e.g. pollinators and biota, Horan et al. 2011, Garibaldi et al. 2011 to soils and crops, Crop Science Society of America 2011, and ecosystem services, Chen et al. 2010, Federoff et al. 2010, Welsh 2010, Chapin et al., 2009, Erb et al. 2009, Schlenker and Roberts 2009, Climate Change Science Program 2008, SAPs 3.3, 3.4, 4.2, 4.3, 4.4, Pimentel and Pimentel 2008, Magdoff 2007, Millennium Ecosystem Assessment 2005, Edwards et al. 1990). the first general reaction is to further intensify agricultural production on the remaining good quality arable land (Crop Science Society of America 2011), and hope to reduce destructive conversion of other lands (U.K., 2011, Federoff et al. 2010, Gibbs et al. 2010) and "land grab" displace of traditional farmers (Hertl 2011, De Schutter and Vanloqueren 2011, DeFries and Rosenzweig 2010, GRAIN.org, Landgrab.org). But can hyperintensification last?

There are serious questions about the sustainability of much of our agriculture (Hertl 2011, Sassenrath et al. 2009, Archer et al., 2008, Magdoff 2007, Edwards et al. 1990) for reasons other than climate and water, including input unsustainabilities and externalities (e.g. nitrogen and fertilizer imbalances and excesses, Chen et al. 2011, MacDonald et al. 2011, Lin et al. 2010, Vitousek et al. 2009, Scheppers and Raun 2007, soil erosion, Pimentel and Pimentel 2008; increasing energy uses in parts of the food system, Canning 2010, and basic production, Patzek 2008; and economic structural problems, Archer et al. 2008, Hanson and Franzleubbers 2008). The global situation increases pressure on U.S. agriculture as a source of exports and "feeding the world" of more than 9 billion with more than 1 billion humans undernourished (Ash et al. 2010) demands "rapid transition" (Godfray et al. 2010: 814) to better than business as usual (Herrerro et al. 2010). And through global markets for agricultural inputs and outputs there are other pressures on agricultural producers and resource owners (Hertl 2011, Gibbs et al. 2011, Lambin and Meyfroidt 2010, De Fries and Rosenzweig 2010, IAASTD 2009, U.K. 2009, World Bank 2008, Halweil 2004, Whatmore 1995). We are globally degrading our productive base, to our economic misfortune as well as environmental degradation (Dasgupta 2007, Arrow et al. 2004, Norgaard 1994).

Sustainability problems inspire the second general reaction to the global situation. Despite the profitability of concentration of agribusiness, and (temporary) increased productivity based on radical increases in inputs of all kinds (Fuglie et al. 2007), there is a rising counter pressure summarized by DeSchutter (the U.N. Special Rapporteur on the Right to Food) and Van Loqueren (2011): "The combined effects of climate change, energy scarcity, and water paucity require that we radically rethink our agricultural systems. Countries can and must reorient their agricultural systems toward modes of production that are not only highly productive, but also highly sustainable." Godfray et al. (2010) call for radical and rapid change. NOAA CPO and SARP work (CCSP 4.3, 5.3) has helped with substantial progress in use of available climate information, particularly for better short-term agricultural water management (e.g. Mondal et al. 2011, and AgroClimate product of the RISA Southeast Climate Consortium), but the efforts are, quite reasonably, in support of business as usual and viability of current modes of production, rather than longer-term transition toward more resilience and sustainability in the coming very different world. Resilience in food security is not a luxury (Welsh 2010, Kirsechenmann 2010, The transition for most of U.S. agricultural land in irrigated farming and in family and small ownership – Two thirds of the land in agriculture in the U.S. is owned by small operations, including a substantial part of the irrigated acreage (Hoppe and Banker 2010). The irrigated land is critical not only for production but because of its role in the hybrid ecology which has displaced pre-development conditions (Wiener et al. 2008, Crifasi 2005). For that land, multi-year crop rotations designed for climate response and resilience and economically viable now are the leverage point and the threshold need for transition, but they may be only the start.

## *The Good News: What is Wanted*

There are, fortunately, three bright spots in the U.S. agriculture and agricultural water picture: desire to conserve and preserve agricultural resources; changing consumer preferences and willingness to pay; and recognition of the concept of multi-functional agriculture. First, farmers themselves want to conserve resources and the lifestyle, and their places as communities and legacies, despite the increasing marginality of small farming under present prices (Sassenrath et al. 2009, Archer et al. 2008). USDA and other research confirms strong allegiance to farming as more than a business (Greiner and Gregg 2011, Sassenrath et al. 2009, Williams 2009, Archer et al. 2008, Shandas 2007, and see constant claims in journals Corn and Soybean Digest (<www.cornandsoybeandigest.com>), the Journal of Soil and Water Conservation, High Plains Journal (<www.hpj.com>). That explains the persistence and florescence of private efforts such as American Farmland Trust, Land Trust Alliance, and other regional and local groups involved in farmland preservation. Every state has some program in recognition of the huge public interests (Hellerstein et al. 2002, Heimlich and Anderson 2001), including those in recreational and amenity value (Reeder et al. 2005, Feather et al. 1999). The agricultural landscape for most people is “a locational amenity” (Lewis 1995), rather than a productive resource, but this is changing. The enormous environmental interests in agricultural landscapes (Sassenrath et al. 2010) are increasingly appreciated, but so are problems for implementation of conservation programs (Atwell et al. 2011; Nowak and Schnepf 2010).

Despite the enormous commercial power of global commodity agribusiness (Lee et al. 2011; U.K. 2011), U.S. consumers (and those elsewhere) show strong preferences for local and organic “short-supply-chain” foods, in direct sales (Conner et al. 2008), community supported agriculture (Russell and Zepeda 2008) and continuing very rapid growth in organics (Dimitri and Greene 2002, Dimitri et al. 2005, Greene 2006, Oberholzer et al. 2008, Tropp 2008, Tropp 2008b, Organic Farming Research Foundation, and see <www.ers.usda.gov/Briefing/Organic/Demand.htm>). Consumers bundle utility from different attributes and show high willingness to pay for organic and local foods with continued price premiums (Lusk and Briggeman 2009, Janssen et al. 2009, Berlin et al. 2009, Lin 2008). A remarkable meta-analysis of many studies showed high levels of consumer awareness, including a shift from “organic” toward “local” as highly preferred, following the U.S. Department of Agriculture promulgation of standards for “organic” (Adams and Salois 2010).

It is also important that over 80% of organic food is sold in conventional markets rather than direct sales, estimated at $16.7 B in 2006, before the latest rounds of price spikes in food. There is a dark side to consumer preferences, in the increasing share of the food dollar spent on processed, prepared, and out-of-home food (Canning 2010); this may mirror the “business as usual but more so” versus “get off the treadmill and go with agro-ecology” split. For farmers, the “alternative” food market is an important opportunity for diversifying their operations, and establishing food chains not controlled by multi-nationals which create competition and promote short-term thinking world-wide (Halweil 2004, Lee et al. 2011).

## The way forward: multifunctional integrated agriculture and agroecology, and research gaps.

The essential idea of multifunctional agriculture is treatment of joint production of the whole range of externalities from agriculture and the whole range of outputs and uses, including attention to not only pollution but visual and amenity values, landscape management, and other public goods provision, and the range of saleable products and even experiences (Zasada 2011). This is especially useful for the peri-urban and intermediate land uses which are vitally important where urban expansion is often on the very best farmland (Federoff et al. 2010, Sassenrath et al. 2010, Hanson et al. 2008; see also <www/iclei.org>), taking an area estimated to be the size of Germany out of farming between now and 2050 (Hertl 2011, DeFries and Rosenzweig 2010). U.S. land conversions have been enormous (Nowak and Schnepf 2010, Lubowski et al. 2006b) though hard to measure (Gosnell et al. 2011) and the area estimated to be in residential development out of highly urbanized areas maybe just as great, with substantial environmental consequences (e.g. Brown et al. 2005, Hansen et al. 2005). “Integrated” agriculture is a similar concept, with more emphasis on linking outputs and products to capture nutrient flows and also achieve the economic benefits of horizontal and vertical integration of multiple enterprises (Hanson et al. 2008). More effective incorporation of multifunctional agriculture in the western U.S. is highly desirable, because of public goods and values noted above, farmer preferences, ecosystem services and biodiversity. Multi-year climate-responsive crop rotations that are economically feasible and can be compatible with current farming priorities (Attwell et al. 2011) are very desirable to support multifunctional multi-enterprise agriculture (Sassenrath et al. 2009) and to promote land use planning that incorporates multifunctionality (Irwin and Bockstael 2007), beyond habitat conservation targeting.

Agroecology is a conceptual linkage helpful for “closing the loops” in local and regional processes, treating the agriculture as part of the ecology and managing for sustainability by adjustments to farming that mimic ecological success in an area (Magdoff 2007), and which increase productive capacity rather than degrading resources (De Schutter and Verlouquen 2011 summarize this; U.K. 2011, IAASTD 2009, World Bank 2008). This is part of the design criteria for a successful multi-year crop rotation for the present and coming situations, and it is mentioned here because this is an important growth in thinking about agricultural progress which is part of that second reaction to the world and national situation. Rather than hyper-intensify with more and more inputs, however marginally unproductive and expensive in externalities, instead, increase production and productive capacity with more thoughtful management. The diversification of multi-functional and ecologically sound production is a critical goal.

Research needs are substantial (Sooby et al. 2007). The productivity of “alternative” agriculture is itself important: are there excessive (or any?) losses in yields from agricultural transition? Badgeley et al. (2007) conducted a huge meta-analysis of organic versus conventional productivity for dozens of crops and places, and report that after an initial decline in some places, as farming is adjusted, losses are not significant, and there may be gains in yield of the crop in question. Perhaps much more importantly, there may be very substantial gains in net total productivity of a combination of crops, net energy consumption, net reduction in toxic and nutrient externalities, and restoration of soil fertility (Gomiero et al. 2008, Baum et al. 2009). Where there are additional yields from joint production with more sophisticated multi-enterprise and multi-functional farming, there may be gains as well as benefits from reduced risks and vulnerability (De Schutter and Vanloqueren 2011, Herrerro et al. 2010, IAASTD 2009, Sassenrath et al. 2009, Magdoff 2007, Bradshaw et al. 2004, Edwards et al. 1990). Unfortunately, there has been very little formal research on organics (e.g. less than 0.1% of the Department of Agriculture’s research through 1995, Lipson 1997). This has limited knowledge of sustainability issues involving soil quality, low-input practices, and multi-year rotations. And, we lack adequate understanding of landscape scales though we know that management must extend beyond farm scales (Sassenrath et al. 2010).

Aside from organic practices, there are very important gaps on any kind of diversified agriculture management. Some of the problem is that these involve highly complex sets of interactions over many years; soil processes and formation can be very slow. These are also controversial issues in some views, and conventional variable-control research is difficult within existing institutions (Francis 2010). Change in agriculture tends to involve whole knowledge systems (McCullough and Matson 2011), in which research interacts with actors’ interests, including demand for particular information. To achieve the “sustainability transition”, there is need for national policy and also regional and local involvement and investment for coordination of efforts and integration of policies (Matson 2009), as has been argued in sustainability science (Kauffman 2009, Clark 2007) as well as in the resilience/regime change theories (Gunderson and Holling, Eds., 2002), and there has been little national policy promoting or supporting change from conventional farming. Basic research on integration of crop and livestock operations has been very limited and is very difficult within current institutional structures (Tanaka et al. 2008), because of research goals of the public institutions, incentive structures for researchers, and demand for short-term projects, as well as the basic difficulties of time, space, and teams. Calls have been made for improved work on enterprise budgets for rotations (Olmstead and Brummer 2008, Attwell et al. 2011), to re-integrate forage crops and perennials for ecological benefits.

## ***Beyond Recommendation, Adoption?***

Research on factors affecting farmer adoption of conservation practices began with the development of agricultural education and the demonstration and extension traditions begun in the 19th Century (Rasmussen 1989), and evolved through diffusion of innovations theory (Rodgers 2003) to more elaborated investigations into the cultural and social factors, “myths” and perceptions, and the adopter group social context (Attwell et al. 2011, Sneddon et al. 2011, Archer et al. 2008; review in Wheeler 2008). The perceptions and attitudes of change agents are also important (Rodriguez et al. 2009). Beyond the “push and pull” for problem-driven research, there are social learning processes affecting adoption of conservation practices (Sassenrath et al. 2008, Social Learning Group 2001). The “bottom line” is that there are very likely local thresholds of interest and then adoption which begin with un-used knowledge, new or recovered, and develop through experiments, testing for compatibility with existing practices and local social/cultural norms, and may hit the ascending limb of the curve of adoption rather abruptly. The surest point is that without efforts to bring new practice to attention, and begin localized adaptation and demonstration, prospects are low. Below, in a different section, the slow increase in conservation tillage is elaborated as an example of lagging progress in a fairly clear case for beneficial innovation.

Farmers cannot afford much blind experimentation, but have made swift changes when the information was accepted and viability seemed probable (e.g. the growth in organics noted, and the massive increase in corn for ethanol). We are just beginning to see some convergence, such as work on biological pest control issues (Landis et 2008), but is seems fair from field observations over the course of these projects that Colorado agriculture suffers from the split into conventional versus “other” agriculture, though there are some signs of progress in the gradual recognition that consumer preferences are not completely represented by the large grocery chains, and the fact that the chains are increasingly buying local and organic produce, organic milk and dairy, and starting to move into meat and grains. Generally, we are not adequately gleaning knowledge from progress in alternative agriculture, organic and otherwise, and applying it to the transition from unsustainable massive monocultures, perhaps most of all because “we” include a research community which may be increasingly dependent on giant agribusiness agendas and funding (Lipson 1997, Halweil 2004, Sooby et al. 2007, McIntyre Ed. 2009, U.K. 2011, Lee et al. 2011). This is not a topic we have researched; it is an impression, but it seems important to appreciate the apparent parallels in pharmacy-medical research (and the pharmaceutical multi-national industry lobbying, campaign finance, and regulatory agency relationships).

As the National Research Council points out (2010), responses to climate change have often been “bottom-up” and locally led. The spread of recycling may be analogous. Getting back to earth, literally, farmers cannot afford much blind experimentation, but have made strong and swift changes when the information was adequate, or incentives seemed secure. A recent example of response to incentives is the fast very large shift to ethanol corn-growing (Wallender et al. 2011) despite lack of support in basic energetics (Patzek and Pimentel 2005). Given the lack of formal research support for organic agriculture (Sooby et al. 2007), and its remarkable growth, it is likely that Wheeler (2008) is correct about farmer “uptake” of information relating to their judgment of credibility of the source. In the West, particularly around rapid-growth urban areas, the pressure on irrigation water has created strong interest in keeping farmers and farms viable (e.g. Statewide Water Supply Initiative, several years, and related publications such as Water Transfer Guidelines, for examples in which NOAA SARP funded research and participation has been relevant). It is the strong impression from more than a decade of field work and interactions in Colorado agriculture that there is significant latent demand for good information about alternatives. The State of Colorado has funded roughly $3 million of projects on alternative agricultural water management, as a concrete expression of interest despite state fiscal crisis. And current work has resulted in expressions that it is very hard to think seriously about alternative crop rotations without better information.

Sustainability as a goal has fostered a large literature on the definition for different purposes and how ideas relate to each other, more than adequately thrashed elsewhere (McIntyre Ed. 2009 coverage, for example).  In terms that relate specifically to the North American prairies, Jackson's work is directly useful: we need to restore perennial crops, and take the future seriously.  The founder of the Land Institute calls for a 50 Year Farm Bill (Jackson 2010), to transition from 80% of cropland in annuals with increasing input dependence and sustainability problems from literally the soil up (and see Baum et al. 2009).  That might feed the world in the long term.

What would a 50 year plan for the Bessemer Ditch and the Lower Arkansas Valley look like? How do we even begin to think usefully about the farmers seizing some control of the situation?

The next section is on the U.S. in particular, and then the following sections describe the regional and local situation in which we will either lose or hold the ground or perhaps make progress.

This report is based on the work done in support of the project we undertook to develop planning-purposed modeling for the Bessemer Ditch, and these conclusions and arguments may seem suspicious.  Readers may compare the 2010 National Research Council report, Towards Sustainable Agricultural Systems in the 21st Century; we were interested to conduct our own study and avoid following what is a much more laborious, well-funded, and authoritative study with the Council's full processes.  It is a considerable relief to report that we are squarely approaching an implementation of what that report calls the pursuit of transformative change, beyond incremental improvement, for transitions toward sustainability.  We leave a full comparison of our work to another paper.

# The National Picture:  Bifurcations, Urbanization, and Innovation in the U.S. and So What?

This section provides a view of some of the national situation affecting the study area, with some discussion of how these issues manifest in the case.

## *Bifurcations*

There are radical bifurcations affecting U.S. Farming, with very large resources are at risk. Above, the loss of middle sized farms was noted, and that is important context because farming is private business – the owners make the decisions, within some positive incentives in the form of subsidies, and the absence of many consequences from externalities, both good and bad, and within an economic framework that makes a long-term approach almost impossible using conventional financing.  This point appears under-studied in the age of pretending that markets need never be structured, work as theoretically ideal regardless of necessary conditions which do not exist (Stiglitz 1993), and are not social choices, however sadly by default; please note that this assertion is by Wiener and not necessarily Dr. Yates and does not represent an institution. National issues that affect the owners' engagement with new water management include changing farm characteristics (Hoppe and Banker 2010) with important consequences for resilience and adaptation goals (NOAA NGSP).  The "small" farms share of sales fell by 1/3 between 1993 and 2003 alone. These farms owned 63% of the private land in agriculture, but produced only 16% of sales, while 84% of sales came from far more intensified large operations that are only 12% of the number of “farms” per se.

In 1997, the percentage of farms smaller than 100 acres was 40.8%. By 2007, this had risen to 48.5%. In 1997, the percentage of farms with sales lower than $10,000 was 50.7%; in 2007, this had risen to 63.9%. And, the middle range is rapidly shrinking in Colorado, as well as the U.S. In 1997, 46% of farms had sales between $10,000 and $500,000, but in 2007 that had shrunk to 32% (USDA ERS Colorado Fact Sheet 2011). The middle, like the middle class, is being squeezed out. There are many hobby, recreational, and life-style “farms” which are called farms on the basis of saying they are farms, because they qualify for the agricultural tax rates (much lower than residential) if there are reported sales of a trivial amount. So the statistics on farm household income are not straightforward, to say the least. Efforts to legislate change in the qualification for agricultural tax rates were finally successful in 2011 (Lofholm 2010). So, the picture is not clear but the loss of farms that support their families is greater than the numbers show, because the small farms categories are so tangled, and because the categories are based on sales (gross) rather than net.

It is also widely thought that there are serious increases in purchases of farms by corporate interests based elsewhere (e.g. comments at Western Governors’ Association invitational conference on alternative agricultural water transfers, 27-28 October 2011, Denver; comments at various other Roundtable and water meetings, and remarks during conversations in the Arkansas Valley; but, there are no known data sources.) That might keep land listed as a moderate size operation, with its own corporate ownership, but allow it to be operated as part of much larger coordinated farming operations owned by a parent corporation managing liability. There is a great deal of local knowledge but perhaps little authoritative regional, state or national knowledge, because this is private property changing hands, and real estate transactions are reported somewhat differently in different states, but for the purpose of taxation rather than the purposes of the agricultural census.

More than 3/4 of federal conservation program payments are to small farms, while the very large ones receive the great majority of commodity support and other payments (Hoppe and Banker 2010). One may doubt that highly-mechanized, input-intensive, fossil-fuel intensive agribusiness will soon convert to more sustainable activities (De Schutter and Vanloqueren 2011, U.K. 2011, McIntyre Ed. 2009, World Bank 2008), especially with very high grain prices expected to continue (Carrico 2011). Small farms are generally already badly stressed with little or no technical support for “voluntary adaptation” to climate change (National Research Council 2010). Some of the Valley farms with irrigation are enjoying those high prices and better net than usual, but for how long? Can these relatively good times last or be used for lasting advantage? What would that be? This report argues for some ideas for the case study, and is intended to support other projects which would work on envisioning better futures, but it seems fairly clear that a farm-by-farm approach is much less likely to succeed than something involving larger areas (Carlson 2003).

The radical loss of farms in the U.S. in the middle sizes shows several important things (see Colorado Fact Sheet, USDA ERS 2011 for the state level view, and Hoppe and Banker 2010 for the national view). One is the triumph of “get big or get out” as a dominant idea in agriculture.

As Dan Henrichs, superintendent of the High Line in the Arkansas Valley put it, once you've got the equipment to farm 50 acres you can farm 75 and that's where you make some money (Woodka, 23 Aug 10, Pueblo Chieftain). There are economies of scale pushing farmers to expand, but they are not all clearly one-way and neither are they unrelated to the economies of fossil fuel subsidies (see Special Issues, Toward a More Sustainable Agriculture, 2011, Critical Reviews in Plant Sciences for recent syntheses; the subsidies are for everything from ownership to production and transportation with effectively no charge for externalities, all the way through to even most of the manufacturing process; Gomiero et al. 2008; see Patzek 2008 on corn and thermodynamics versus the market structure. And see the Economic Research Service (USDA) <http://www.ers.usda.gov/Briefing/Corn/background.htm> on the U.S. dominance of corn as feed grain). The economies change with the costs of inputs and the kinds of farming. This includes choices about monocultures that demand simultaneously handling very large areas of crops with a lot of equipment needed or farming multiple crops that can call for different implements used in sequence but less capital investment in traction (see National Research Council 2010b; Baum et al. 2009).

There is another bifurcation in the way information is created and incorporated into practice. Moving to implement concepts of multifunctional integrated agriculture will require decision support for Western farmers, and must also be compatible with more efficient and climate-responsive water management. But there are substantial difficulties in the present research institutions for work on mixed livestock and crop farming (Tanaka et al. 2008), developing enterprise budgets for crop rotations (Olmstead and Brummer 2008, Atwell et al. 2011), and work on agricultural sustainability with regard to reducing inputs and conserving soil (Gomiero et al. 2008, and see Baum et al. 2009 for one sophisticated effort) in more complicated farming systems. It is important that conventional agricultural research institutions seem to provide little or no support for alternative agriculture (Kauffman 2009, Gomiero et al. 2008, Sooby et al. 2007, Lipson 1997), which unfortunately supports a culture of rejection of all kinds of agriculture other than the dominant conventional commodity production in many cases (Rodriguez et al. 2008). There may be serious bifurcation in the knowledge communities in conventional and commercially-supported land grant university research and applications versus organic and alternative agriculture (Wheeler 2008; Sooby et al. 2007, website for Organic Farming Research Foundation, and see McCullough and Matson 2011 on knowledge communities; Mero 2011 reports only three university programs in the U.S. on organic farming). The result is that there is a gap which Francis (2010) describes as unconventional problems versus conventional research.

The relative prices of inputs and fuel must not be assumed to be static, or even close to stable (Huang 2009; Wiener 2008). In the enterprise budget for center-pivot irrigated corn nearest the case study area, for example, purchased inputs to farming including bought seed, fertilizers, herbicides, insecticides, aerial spraying, irrigation and other costs were $539 per acre, out of total direct costs of $666, which does not include the cost of ownership of the land, thought it does include the real estate tax; these figures are for 2009 and also do not include the cost of labor by the owner or tenant farmer, or if a tenant, the costs of the lease; Colorado State University 2009; and see Wiener 2011). In that enterprise budget, the room for profit depends on good yields and good prices for the harvest. Note that enterprise budgets are economic calculations based on expert knowledge of a regionally representative good farmer, not the best nor the worst. A typical center pivot irrigation system will water 127 acres. A typical flood irrigation system will water 140 to 150 acres out of the usual field size of a quarter-section, 160 acres. These numbers, over $68 thousand for outlay for a single field with a center pivot (not counting some of the costs of the pivot and the loans and the cost of the land or water rights), illustrate that this is not a trivial business, and that starting in it is very expensive, and that with costs this high, changing course is also a significant challenge.

It is also misleading to overlook the structure of markets and distribution chains, which are increasingly concentrated all over the world as well as in the U.S. (Hendrickson and Heffernan 2007, McIntyre Ed. 2009, Ranchers-Cattlemen Action Legal Fund 2010, U.K. 2011). This concentration affects production through contract farming and standards for what will be purchased (Whatmore, 1995, Halweil 2004, Hanson et al. 2008, and other articles Renewable Agriculture and Food Systems special issue 23(4), Lee et al. 2011). There is a counter-pressure which is relevant to the Arkansas Valley and the Western U.S. in the changing consumer preferences discussed below, but the trends are strongly for bifurcation in the U.S., noted above and below. There is also an international (and U.S.) change in the massive but not well tallied "land grab" by governments and multi or anti-national corporations buying farmland for use in export production, with complicated and often very undesirable impacts on displaced subsistence and regional-market farming, dispossession or displacement of farmers, and conversion of long-term farming methods to monocultural heavily-input dependent plantations and industrial farming (McIntyre Ed. 2009, DeFries and Rosenzweig 2010, Gibbs et al. 2010, DeSchutter and van Loqueren 2011, Lambin and Meyfroidt 2011, Hertel 2011, U.K. 2011, and see <www.GRAIN.org>).

Urbanization and conversion of good farmland is another factor which will affect agriculture; the Presidential Address to the American Agricultural Economics Association by Hertel (2011) reports additional urbanization loss of prime farmland about the size of Germany by 2050. In the United States, the National Agricultural Lands Study was regarded as highly ominous and significant in 1978, but is now apparently not available on the internet (see United States Department of Agriculture and others, 1978). In Colorado, see Environment Colorado (2006) and Carlson and Leeper (2004).

The bifurcation of farming also shows the increasing importance of the remaining peri-urban areas of prime farmland, increasingly converted to non-agricultural uses as the "development" process expands. The loss of agricultural capacity is hidden by the massive substitution of energy, equipment, and inputs for land quality so that market signals are defeated by subsidies and temporary unsustainable substitutions.

## *Challenges for Urbanizing Areas: Moving toward multifunctionality?*

There is a great deal of literature on the changing land uses affecting agriculture, particularly concerning the conversion of farmland to non-commercial agriculture purposes and some of the consequences of sub-urban, peri-urban, and rural residential development. One might begin with the National Agricultural Lands Study (1978) if one has access to a printed copy (see brochure, U.S. Department of Agriculture and others 1978), and Castle, Ed, 1995. On ecological impacts of these changes in rural residential development, with disproportionate impact, see Brown et al.

2005 and Special Section, Ecological Applications, Land Use Change in Rural America , Irwin and Bockstael (2007), Clark et al. 2009, Sassenrath et al. (2010) for a sampling of literature.

On the subject of how agriculture at the edge is currently faring, one outstanding report on what was working for farmers during the hard times of 2005-2007 came from a comparative study of 15 U.S. counties, including Larimer in Colorado, by Esseks et al. (2009). The value of this study for the Bessemer Ditch and Arkansas Valley is in its review of what the agricultural community perceived and demonstrated in practice. It should be noted that measuring the effectiveness of farmland preservation programs is very difficult, involving comparisons of what are in practical terms some hypotheses about "with and without", and applying them as land use projections which are compared with outcomes that have been affected by the whole range of factors in land conversion; there is an excellent discussion of this provided by Gosnell et al. (2011).

All of the urbanizing counties had some forms of protection in laws, including agricultural use tax rates, though as noted this is a problematic area, and some form of "right to farm" (though effectiveness was said to depend on enforcement and conflict resolution). The defense of farming in urbanizing areas is not solely for non-market reasons; Esseks et al. note that in the 1997 Ag Census, 86% of U.S. fruits and nuts, 86% of U.S. vegetables, and 63% of U.S. dairy came from metropolitan areas; in the 2002 census, 55% of U.S. farm sales were from the rural-urban interface area (p 14; see also Gale 1997 and discussion in this report on consumer preferences).

The Esseks et al. study found that direct sales were often substantial in urbanizing county farm economics, including median direct sales from the sample in Larimer of almost half of all sales. Two thirds of sales in the urbanizing counties were made within an hour travel time from the farm (p. 43). Proximity to buyers and processors was thought very important. Nursery, greenhouse, floriculture and sod grew rapidly in Larimer, almost doubling 1997-2002, and this category was in the top three in 12 of the 15 counties (pp 32-38).

It is important that the most common request for assistance was for help in diversifying or adding new products. Second to that was request for help in marketing. Though not used there, the term in this report is multifunctional agriculture, or multi-enterprise agriculture. The implications are that despite the labor issues, the high-value products and the diversification of enterprises seem critical in the ability of small farms to hold on to good land despite sprawl, partly by avoiding competition with the conventional commodity producers. This is not geographically specific, as the Esseks et al. study shows.

And, the good news, bad news is that while some are adapting to urbanization, it is by these "alternative" kinds of farming, but there is a great deal of pessimism, echoing what Wiener encountered in the Arkansas Valley. In Larimer County, CO, 52% of the farmers expected some part of their land to be out of agriculture in ten years. And in Larimer, of the farmers under 55 years old, only a third expected to be in farming in ten years. The conflict in this is clear: the investments needed to diversity and to move into high-value enterprises may be irrational if there is a short future ahead. Therefore, it is unfortunately likely that the choices are for increasing use of labor rather than long-term capital investments, and since the Esseks et al. studies were done, that has exposed the farmers to the politics of demagoguery regarding immigrants and farm labor fall-out problems.

It is possible that there may be an ironic benefit from some of the politics of recent years and the impacts of climate change (please note: this is Wiener only writing this). The traditional school calendar and timing reflected the role of children in farming and family business. Over the years, it may have crept away from that to favor other interests and disfavor child labor. Now, there is consideration of changing the calendar because of the perception of increased summer heat and the lack of investment in school infrastructure resulting in very uncomfortable schools. Perhaps kids will be able to go back to helping on the farm.

Less speculatively, the Esseks et al. study also shows the race between land conversion and the expectation of farm loss versus the counter pressure from changing consumer preferences for local food and the increasing recognition of the values of agriculture for amenity and recreational purposes. The outcome may depend on the will and ability of agricultural groups to take control of their own resources. The essential problem of moving toward multifunctionality and increasing diversification is security of expectations: when does it make sense to invest? In terms of what is farmed, who would plant vines or an orchard without expectation of being able to get to harvesting fruit? In terms of how it is farmed, what are the times needed to amortize investments in new infrastructure, whether advanced irrigation technology or water distribution, or equipment for different crop rotations or even moving toward certification for organic status? The lack of stability in areas like the Bessemer is critical. The lack of succession and future certainty of farming by families may be critical in areas both urbanizing and not. In some rural areas, the declining services and community issues may also be important in losing farm families. Without some stability, everything is harder. Property rights exist to provide stability, but will they be used to move forward or only to hold to “good fences make good neighbors” until the other side of the fence is a subdivision or a multi-national corporation producing an input for its vertically-integrated operations, using its own inputs, cheap labor, and taking away the profits and outputs, or another experiment in invasive weeds?

## *Conservation Tillage as Example of Innovation, or Not…*

Another national situation with important influence on Colorado and the case study reflects the distribution of property rights. Private ownership is taken to include the right to destroy a resource, limited by extreme or perhaps one should say obvious imposition of costs on others such as nuisance smoke. Agriculture is exempt from non-point-source pollution control regulations (Nowak and Schnepf Eds. 2010, Sassenrath et al. 2010), and so is unusually free of consequences for the costs of off-site sedimentation and water quality impacts, both surface and groundwater. The incentives for management are not much affected by negative externalities from farming and other agricultural activity other than some regulations for concentrated animal operations with point-source outputs. The soil is regarded as private property, and the history of soil conservation is too much to cover here, but can be summarized for the U.S. as a series of public programs seeking to provide financial incentives and education about private and public benefits (there are huge resources on this available from the Economic Research Service and the Natural Resources Conservation Service of the U.S. Department of Agriculture). One of the important results of the distribution of rights we face is that the public has the benefit of some private purchases by Land Trusts and other private groups, and some public agencies, which use conservation easements and similar devices to stabilize land use and promote soil conservation. These programs are much smaller than the federal payments which rent conservation behavior, such as the Conservation Reserve Program, which pays for desired forebearances but which is optional and can be ended by a participant. There are some programs with more durable investments, such as farm improvements with cost shares from the EQIP and other programs, which are all a fraction of the commodity payments supporting production however achieved (summaries of this are particularly well presented by the Environmental Working Group 2011 report, “Losing Ground”, but there are also huge resources with different analytic and political purposes from the Economic Research Service).

Conservation tillage – a large category of reduced soil disturbance farming techniques – is a rather clear example of the problems of positive incentives for short-term production and only moral incentives for the very long term, and few implementations of the public interest because that public interest must be represented by money. The ownership includes the right to destroy, and we rent or buy that back, or not. Economic theory clearly describes the problems of a high discount rate (meaning, that the future is worth less or as the rate gets higher, much less than the present) and the very slow rates of soil formation (McConnell 1983; Clark 1973, and dozens of references in economics, such as Bromley, Ed., 1995). The purpose of plowing this old ground again is to show that unless we change some rules of the game, the outcomes are not good.

Sampling from a large literature on conservation tillage, it has long been clear that there are substantial off-site (public) benefits from increased nutrient and soil moisture retention, decreased sedimentation, and changes in run-off timing (e.g. Allmaras and Dowdy 1985, Allmaras et al. 1991). The question was whether reduced costs of production would induce acceptance in any given regional cropping system. Before climate change was appreciated, and the tremendous promotion of GMO crops, a synthesis of knowledge by the National Research Council (1993) included the following statements in the Preface:

> *“The list of environmental problems on the agricultural agenda has grown in the past 15 years. The long-standing concerns about soil erosion and sedimentation have been supplemented with new concerns about soil compaction, salinization, and loss of soil organic matter. The transfer of nitrates, phosphorus, pesticides, and salts from farming systems to surface water and groundwater has also become more important.*

Efforts to address the larger complex of environmental problems has been hampered by concerns about trade-offs. For example, best-management practices designed to reduce soil loss are now scrutinized for their role in increasing the leaching of nitrates and pesticides to groundwater. Other trade-offs arise between efforts to improve agriculture's environmental performance and efforts to reduce costs of production and maintain U.S. agriculture's share of world markets.”

National Research Council 1993: p 6 of Executive Summary: “Conservation tillage and residue management systems are well understood and effective means of reducing erosion and runoff. A great diversity of tillage and residue management systems is available to producers. Many of these systems result in dramatic decreases in erosion and runoff from farming systems and from agricultural watersheds. The major opportunity to improve the effectiveness of these systems is to increase their use on lands that are most vulnerable to soil quality degradation or that most contribute to water pollution. In some regions the applicability of these systems may be limited, however, because of unfavorable physical or economic factors.”

National Research Council 1993: p 7 of Executive Summary: "Much of the damage from erosion and runoff can occur during storms that occur infrequently. Incorporating the probability of storm events into the design of farming systems should help identify approaches that combine residue management with changes in cropping systems to provide more protection to the soil during periods when storms are likely. Current computer simulation capacities coupled with available climatic data should be used to identify opportunities to design farming systems that can resist damage from storm events of various duration and intensities."

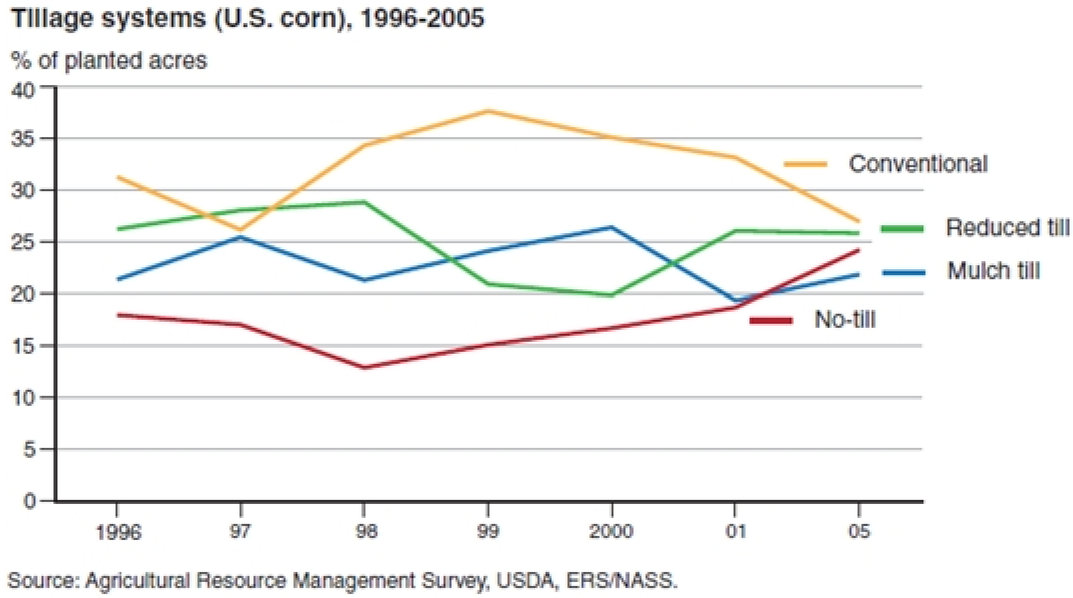
That quote is poignant now, with our understanding of the already observed increased intensity of precipitation and its erosive effects (Soil and Water Conservation Society 2003, Climate Change Science Program 2008a, 2008d, 2009). And one must add that the incorporation of climate information into agricultural decision-making has been inconsistent, to be charitable, despite some excellent advances in decision support (e.g. NOAA SARP supported work such as AgroClimate). Drought has stimulated more response, including regional work on water management and decision support for irrigators from extension and research groups in Kansas and Nebraska as well as Colorado, and research on techniques such as deficit irrigation (Central Plains Irrigation Association annual proceedings are particularly regionally tailored research). There has been considerable work on the soil moisture benefits from crop residues and tillage reduction or timing. But the erosion damage from storm events remains extremely problematic, as shown by the close monitoring in Iowa in a study by Iowa State and Environmental Working Group (2011).

National Research Council 1993: p 9 of Executive Summary: "Encouraging or requiring the adoption of single-objective best- management practices is not a sufficient basis for soil and water quality programs at the farm level. Inherent links exist among the components of a farming system and the larger landscape. Adoption of a tillage system that increases soil cover to reduce erosion, for example, may require changes in the methods, timing, and amounts of nutrients and pesticides applied. Failure to recognize and manage these links increases the cost, slows the rate of adoption, and decreases the effectiveness of new technologies or management methods."

National Research Council 1993: p 11 of Executive Summary: "Research and development of economically viable cropping systems that incorporate cover crops, multiple crops, and other innovations should be accelerated to meet long-term soil and water quality goals. Innovative cropping systems use cover crops, companion crops, strip- cropping, reduced reliance on fallow, or other changes in the timing or sequence of crops. Such systems can be designed to increase soil cover; reduce insect, disease, and weed problems; utilize excess nutrients; and control runoff and leaching from farming systems. These innovations in cropping systems may prove to be the most effective way to protect soil and water quality while sustaining profitable food and fiber production. Guiding the research to develop new cropping systems requires a long-term perspective and a vigorous imagination. Existing cropping systems have little resemblance to the systems common 75 years ago. It is reasonable to expect that future systems will be equally different from current systems." And yet, we know of no regional work on enterprise budgets for multi-year crop rotations or climate-responsive flexible multi-year rotations. The problems with such research are noted elsewhere; this is outside the scope of what is done affordably following the model of controlling all but the independent variable in careful trials (Tanaka et al. 2008). It is also notable that the 1993 report endorsed a landscape approach (chapter 12), still apparently not accepted outside the literature (Sassenrath et al. 2010 and meeting workshop discussions, Managing Agricultural Lands for Environmental Quality II, Denver, 2008; Wiener observations as participant).

The bottom line, however, was that the 1993 synthesis found that only 31% of highly erodible land used for corn had some form of conservation tillage and that the fate and transport of biocides used were not adequately understood (National Research Council 1993: 99-100, 331, 351-355), and most importantly, that adoption rates were disappointing. Uri reported in 1998 that conservation tillage may be adopted more widely with education programs where it would be privately profitable, but financial incentives may be needed where it would not increase profits but would provide "substantial offsite benefits", particularly related to sedimentation, eutrophication, and pesticide contamination [and one would add herbicide]. High discount rate decisions for a short time frame may discourage investments in practices that increase returns over the long term. Conservation tillage is seen as more risky because timing is important and there may be greater variability in yields. At the time of the reported survey, almost half of the farmers in surveyed counties said they knew nothing about conservation tillage. Private benefits from soil quality improvements and reduced erosion are long-term and should increase yields over the long term and increase value of the land, but had not affected the outcome as much as one would hope. Compliance requirements for qualification for other federal agricultural assistance had been effective in promotion of conservation practices, including rental conservation, on roughly half of highly erodible land. There seems no doubt about the potential benefits of increased adoption (Holland 2004, Wang et al. 2006) in other countries, but U.S. producers still doubt that the private benefits are greater than the private costs (see Archer and Reicosky 2009).

The USDA recently reported data as of 2005. No-till and mulch till are conservation tillage practices that leave at least 30 percent of the soil covered by crop residues after planting, while reduced-till leaves 15-30 percent and conventional tillage leaves less than 15 percent of the soil covered. Reducing soil erosion and mitigating the impact of higher energy prices are both motivations for reducing tillage. The use of no-till in U.S. corn production has been increasing since 1998, and conventional tillage has declined since 1999. Herbicide-tolerant (HT) crops became more popular over this period, as these crops allow the application of glyphosate directly over post-emergent plants to control a larger weed problem often associated with no-till. This chart comes from the ERS report, *On the Doorstep of the Information Age: Recent Adoption of Precision Agriculture*, EIB-80, August 2011." [Schimmelpfennig et al. 2011.]




Bu even with the huge adoption of GMO herbicide-resistant corn, according to the Conservation Tillage Information Center (2011), still less than 41% of corn acreage has some form of reduced tillage.  The point of this small look at conservation tillage is that it illustrates clearly the conflict between individual private interests while on the treadmill of short-term decision-making and a high discount rate versus both the long-term maintenance of agricultural productive capacity as an asset held by a private owner of land, and the short-term public interests in reduction of the externalities imposed by soil erosion and agricultural non-point pollution, and the long-term public interests in food security and productive capacity.

## *The Bessemer Case*

(Please note: this report is accompanied by a set of photographs of the Bessemer Ditch and some other illustrations and maps, but for purposes of e-mailing and working with elderly equipment, they are not included due to file sizes.  A later edition will be done with some means of presentation, probably on a website.)

The Bessemer could be a model of long-term management, with its combination of physical conditions.  On the one hand, the soils are highly erodible (NRCS 2001), but on the other hand there are conditions favoring use and perhaps significantly increased ecosystem services from the drainages that cross the area, and the remaining riparian areas along the Arkansas River.  The re-vision ideas include increasing the wetlands on the south side of the ditch, as illustrated elsewhere, and some additional increases in conservation areas.  The Salt Creek drainage is substantially affected by encroachment, but there is a wide diversity of conditions in the Blende area on the West, more heavily developed into much smaller parcels than the Vineland central area, or the Avondale eastern area.  The Saint Charles drainage is encroached upon in larger and less-developed ways, as a gross generalization, and the major challenge may be dealing with limiting future development and managing the Tamarisk and Russian Olive infestations.  The Six Mile drainage is also encroached upon, but with less intensive uses than the Salt Creek, as another gross generalization. The vegetation along the Six Mile appears from very limited views along public access to be somewhat less invasive than the Saint Charles, perhaps reflecting the different drainage areas for these creeks. The Saint Charles drains a much larger area as well as a more intensively developed part of the Bessemer, which one supposes would provide steadier levels of domestic use as well as irrigation return flows. Finally, the Huerfano River drainage which borders the east end of the Bessemer is supplied by less return flow from irrigation but a considerably larger catchment area (U.S. Department of Agriculture Natural Resources Conservation Service 2001, 2007). Therefore, one supposes that the Huerfano breaks area, where the river has eroded down into the mesa, may serve well as another riparian buffer. It may be worth more intensive examination of the potential of these drainages for improved filtration and wildlife connectivity functions than this project could undertake. In terms of conservation tillage and other practices, it appears that the highly erodible soils here could benefit from increased efforts to retain soil quality and reduce erosion rates as well as nutrient losses, in turn supporting lower-input farming.

The bigger picture of agricultural innovation, however, remains dismal (see summary in Wiener 2005 posting), and the bottom line is the bottom line. There are very important issues of information acceptance and information provision (Rodriguez et al. 2009, Sneddon 2008, Wheeler 2008) and in the end, who believes whom. That brings us to the next sections of the context in which the case study is located and the situations in which the owners will decide the fate of the Bessemer, as an example of so many places at risk.

## The State Picture: Colorado Begins Planning but Acts Very Cautiously – Statewide Water Supply Initiative, and Interbasin Compact Committee Processes

The drought centered on 2002 in Colorado and the Southwestern U.S. was remarkable for its severity and extent, compared to the European period in the U.S., (Cayan et al. 2010, Pielke et al. 2005) and Colorado was moved away from its historic position that “prior appropriation water law is our plan.” The steadfast refusal of a state role in water planning had been slightly eroded by federal requirements of state involvement and the gradual modernization in recognition of public interests in minimum in-stream flows in some places, and the public interests in recreational and amenity as well as environmental uses of water (Corbridge and Rice 1998). The planning role had been limited to minor involvement in environmental assessments and some limited oversight of water projects, mostly advisory, and a larger role where there was state funding involved, as in some power development, and some loan programs. There had never been anything like, for example, the California Water Plan, perhaps because the great water projects in Colorado were federal or municipal. The 2002 Drought changed discussion, although it was years more before there was public discourse in polite or political company about climate change. There had been a series of Drought Plans, and there was an update in 2004.

The first major response beyond drought may have been the failed referendum to tax to fund a very large water project, which was not specified, but thought to be surely a transbasin diversion bringing more West Slope (Colorado River Basin) water to the Front Range (East Slope) metropolitan metastasis. The failure of the referendum helped stimulate a different response, in the Statewide Water Supply Initiative (SWSI). This involved a series of studies of water supply, and demand, in each river basin and the use of “roundtables”, which included representatives of different interests who were appointed by the Governor, counties and municipalities. These were continued and formalized in the Interbasin Compact Committee process, established in 2005, which also brought in another group from those appearing and seeking to represent other sectoral interests, including industrial, agricultural, recreational, and environmental. There were also a series of Technical Statewide Roundtables, and summary processes as well as substantial contracted research and reporting. (The researchers on this project and previous NOAA SARP and predecessor projects would like to expressly thank NOAA for making it possible to participate in two of the basin roundtables in SWSI, and four of the technical roundtables, and then the IBCC process, continuing involvement in the Arkansas Basin quite actively through 2010, including service as advisor to the Water Transfer Guidelines Committee of the Arkansas Basin Roundtable.)

The SWSI process continues, and has been thoroughly reported with extensive publication available on the website of the Colorado Water Conservation Board, with several major updates to the reporting done, most recently in 2010. It is a multi-dimensional process in which each basin roundtable plays out local differences and preferences, while performing some functions in allocation of water project funding, and more or less supervising contractor work on Consumptive Water Use Needs Assessments, and Non-consumptive Water Use Needs Assessments.

The essential move toward planning reflects not only the “gap” between projects and processes for meeting water needs versus projected water demands given continuing forecast very rapid growth of population and increasing demands for recreational and environmental uses. The move also reflects increasing rural and local resistance to water transfers, and the gradual increase in power to impose high transactions costs on transfers, beyond the already quite high costs of formal judicial processes. Although it has not been mentioned, to our knowledge, one of the important reasons for planning by the State is the need for support for the smaller water providers who are technically often limited to simply operating their systems, without any of the kinds of long-range planning and investigations of potential supply used by the large systems. It is somewhat odd, on reflection, that a doubtless not unknown consequence of the “market only” philosophy of Colorado water law – “prior appropriation is our plan” – has been the pretense that the world-class Denver Water Board, Colorado Springs Utilities, City of Aurora and Pueblo Board of Water Works are all just the same as an individual thinking about a well or a system that serves 86 customers. All should be regarded as similarly situated contestants on a level playing field, with the exception of the utilities far more commonly using the conditional water right (Corbridge and Rice 1999). The recognition of capacity differences has been made in water quality and treatment discussions, such as EPA’s workshops on water infrastructure, but the other great pretense of there being no link between water quantity and water quality has foiled any cross-over as we know. So the State finally entering planning should serve to at least help the interests with little or no access to technical support.

The difference in information (and public information) and the State non-involvement is especially important because of the closed-door nature of water policy setting, as recently emphasized by a very important privately negotiated agreement between Denver Water and others on the East Slope and the Colorado River District and others on the West Slope. This agreement will affect future transbasin diversions and mitigation of changes planned or contemplated, including use of water rights already owned, and was widely heralded as very important progress in water policy. It was apparently not publicly noticed that this took place while the public, open Interbasin Compact Process trundled on, with some of the same people, making no apparent difference beyond increasing the warm glow of self-appreciation for talking. (Denver Water Board 2011, Finley 2011). It was known that the parties were talking (Associated Press 2005), but these were private negotiations by parties not obligated primarily to any public interests beyond their own views of their obligations to their own water rate payers or other constituents or charter. The general and long-term public interest was not necessarily involved and was considered to some extent as a generous gesture. The State's long default may finally be coming to an end in the provision of information, as in the Statewide Water Supply Initiative projects but the on-the-ground policy impacts are not yet apparent, beyond a tremendous volunteer effort and contracting for studies. Meanwhile, business as usual goes on.

In the public arena, whether or not there are effects, the Statewide Roundtable Summit on 03 March 2011 reported, regarding the future of agriculture in Colorado, that the status quo "leads to a significant reduction in irrigated acres… Such a large-scale dry-up would have adverse economic and environmental impacts. In addition, the state's agricultural economy is linked: a concern is the potential diminished ability for cattle to be finished and slaughtered and for agricultural products to be worked into the supply chain. There is therefore a statewide vested interest in preventing the status quo. In addition, there are upward pressures on agricultural economies from the need for food security, proximity of food supplies to population centers (buying locally), and the need to feed the 5 million new people. Therefore, dry-up is not inevitable." Municipalities demand permanent supply and prefer to own the water rights and lease-back use until needed or to lease return flows to augmentation programs. Farmers were urged to see the benefits of rotational fallowing. (These ideas are described in the section on Colorado's alternative agricultural water transfers program).

In 2007, the percentage of Colorado cropland irrigated was 20.0%; it was 25.3% in 1997 – a loss of one fifth of irrigation in ten years (U.S. Department of Agriculture Economic Research Service 2011 "Colorado Fact Sheet"). We are losing ground for many reasons.

## The Arkansas Valley Super Ditch Project

There are a set of six funded projects on alternative agricultural water transfer methods in a Colorado grants program, discussed in the next section. The longest running effort, with frequent funding from the Lower Arkansas Valley Water Conservancy District and the State, is the Super Ditch project (public funding has exceeded $2.5 million; Nicholls, 2011). This is an effort to carry through the studies needed, and the education and persuasion needed, to organize a rotational fallowing and water leasing program in which shareholders – the owners of water rights – from seven major ditches in the Lower Arkansas Valley can participate. There are real advantages to pooling supply from many ditches, to increase reliability and possibly decrease impacts from the transfer where the marginal changes in each ditch may be much smaller than if the same volume were taken from fewer flows. Intensive work on organizing the studies and potential participation began in 2006, but the Lower Arkansas District was created by election in 2002, after some years of work organizing that. The District was the first new cooperation among the otherwise competitive ditch companies in a very long time other than some common responses to water management issues which were mostly related to the ideas for expansion of the Frying Pan-Arkansas Project and additional water storage. The Lower Ark District was something of a turning point in beginning pro-active responses to the general problem of sharply increasing municipal water demands. History of the District and the Super Ditch project, the premier work of the District, is provided by Nichols (2011), the attorney for the District and the Super Ditch project, reporting to the Colorado Water Conservation Board. Before that, the main focus in regional water innovation ideas was the ill-fated Water Bank Pilot Program. The series of efforts to buy and move water from the Valley probably held center stage for most of the irrigators and their allies throughout the 1990s and 2000s, as sales were sought, some consummated, and projects were suggested. The one constant was the one-way flow of water, intermittent as it was, out of Valley agriculture to other uses or to retention as leased-back water with ownership in other hands.

The Super Ditch was not the only innovation, as there were two very important successful short-term leases of water from the Rocky Ford Highline Canal Company and shareholders to the City of Aurora, and Colorado Springs. To distinguish easily, this is usually called the Highline, since there is also the Rocky Ford Ditch not far away. These deals were made without much public awareness and with a strong will to accomplish transfers quickly, as the motives were the need for water for Aurora for drought recovery, later joined by Colorado Springs, and the recognition by the High Line management and a majority of shareholders that money for the water was better than an insufficient amount of water to produce profitable crops. Part of what made this attractive was the lack of a good mechanism within the ditch to pool resources and optimize water use, as an internal market, but even if there had been better internal re-allocation, it is important that the city partner put down a lot of money for internal structural improvements which provided a long-term benefit to the ditch. This took place while the farmers were in some cases literally weeks away from foreclosure (interviews and many conversations with Dan Henrichs, Superintendent of the Rocky Ford Highline Canal Co).

The two Highline leases proved to many people that a temporary transfer could be beneficial, and this provided substantial impetus for the Super Ditch project. There was a substantial advantage in the early and competent involvement of High Line management in working out what terms would benefit the ditch and the shareholders, rather than the much more public and protracted arguments that took up a lot of time in the Valley on whether or not such a thing could be good. The terms of the lease were very favorable to the High Line and its participating shareholders, largely because of the unusually severe needs of Aurora and the infrastructural capacity to physically manage the transfer because of its up-stream diversion and pumping plant shared with Colorado Springs. Such favorable terms were not likely to be common, but they made the point that there were gains from trade to be pursued, and that the farming consequences were not as bad as some had feared. It is important that one of the very serious problems in fallowing land is weed infestation, and that problem is not as great during severe drought. The extreme soil moisture deficits persisted for years before and after 2002, which helped reduce growth. There were serious problems with weeds, even so.

The Super Ditch project continues, and has held attention partly because of the strength of much of the technical work funded to assess the project, and partly because the process has been largely transparent. Some of the negotiations with potential lessors have been private, but more has been made public about this project than perhaps any non-federal water project ever in Colorado. It is noteworthy that the High Line leases were short-term and conducted under existing authority for short-term transfers, and the Super Ditch is contemplating considerably longer terms.

But, the Super Ditch has not apparently sought permanent transfers, and so falls short of the recommendations from this project, and the goals which this project sought to support. We started working to support decisions about climate-responsive water transfers which we expected would be fairly long-term but as noted above, the felt need changed to effectively permanent arrangements which would capitalize or support financing transition to much more sustainable farming and partnerships. The problem has been redefined, and for better or for worse, the non-modeling aspect of this research is still either ahead of the present efforts, or out in left field. When we started this line of work, in 1997, any kind of leasing was regarded as absurd, and any kind of climate-informed water management was treated with great suspicion, and that has changed. So, we have not yet quit.

The important role that the Super Ditch plays now is in increasing the credibility of new ideas and the mustering of top-shelf legal and engineering talent in working through plans and possibilities. The studies done provide quite substantial support for a lease should one be consummated. They include not only estimates of foreseeable costs for infrastructure improvements, but also analyses of possible conveyance out of the region, and terms of leases which might serve as templates for deals.

It is hard to predict the impacts of the next serious drought, as severe dryness continues in the southeast and San Luis Valley of Colorado, even while there were good flows in the Arkansas River. This may mean continuing very persistent vulnerability to the appearance (or not) of a few highly productive storms in the headwaters, which may be less reliable than in the past (e.g. Cayan et al. 2010 and associated articles in special section in Proceedings of the National Academy of Sciences). This has not been publicly discussed, as far as we know, in relation to the Super Ditch, but the relative productivity of dryland versus irrigated farming may be changing in some important ways. The consequences of change in range conditions are also unclear, for the cattle businesses and the cattle feed business, which is the majority of irrigated agriculture in Colorado. It is possible that the leasing which Super Ditch may arrange with Aurora and the Pikes Peak Regional Water Authority (fast-growth rural exurbs in the Colorado Springs and South Denver areas) may become more lucrative and more attractive due to such large scale changes.

At this time, however, the State program and the Super Ditch are holding attention, and focusing thinking on what are short-term and medium-term water management changes. The variability in irrigation supply and the recent high prices for corn (leading agricultural commodities and feed in general) have probably served to reduce interest in the long term and deflect attention away from the continuing loss of farms. It is not possible to make this claim scientifically, but there is a strong sense in many of our encounters over the years that family farms are doomed, and that selling water is a critical option and one which may have to be exercised sooner rather than later as the cities will not want it all, and the chance to pay off debts and have something to pass to the next generation may slip away.

The volumes in the two “terms sheets” described by Nichols (2011) include 8020 acre feet per year for Pikes Peak Regional Water Authority, for terms up to 40 years, at $500 per acre foot, to be adjusted every five years, and similar prices for Aurora but within the three years out of ten years limit of use, following a different statutory authority for transfers, until 2048., with a total of 133, 197 acre feet. The Pikes Peak Regional Water Authority expressly retains the right to conduct other acquisitions in the Valley, which might include sales from Super Ditch participants. Aurora is limited in its purchases from the Valley by a set of other agreements. These “terms sheets” are not binding unless contracts incorporate them.

The importance of the Super Ditch project continues to increase. At the meeting on alternative agricultural water transfers held by the Western Governors’ Association on the 27-28 of October 2011, the Super Ditch was presented as a major case study in the report to be presented to the Governors.

Super Ditch was legally incorporated on May 7, 2008, after substantial planning and investment of legal talent (Nicholls 2011), and at that meeting there was talk of three critically important prior events. First, the formation of the Lower Arkansas Valley Water Conservancy District was based on a popular appreciation of the goal of keeping water in the Valley. Second, there was a lease of water, perhaps the first time from agriculture to municipal uses on a large scale in Colorado, from the Rocky Ford High Line Canal (called the High Line to distinguish it from the Rocky Ford ditch, which had been sold to Aurora in the 1980s and 1990s). The lease took 18 months to organize, according to Dan Henrichs, Superintendent (many conversations), but in 2004 water was moved to Aurora, and in 2005 water was moved to Aurora and Colorado Springs, in both years for drought recovery from the severe drawdowns in the 2002 and 2003 drought conditions. The lease literally saved some farmers from foreclosure, and it made the point far more effectively than our years of discussions that a poor or failed crop using a little water was worth less than decent money for the water. With shrewd negotiations and serious desire for the water, those leases were quite lucrative for the farmers and supported important infrastructural improvements to the High Line. This also established, beyond discussions, an important point which we had previously discovered in our NOAA-funded efforts: the ditch equipment is very important for flexibility of water re-allocations and after the 2002 financial beating some ditches were worried that even if they wanted to try leasing, they would be facing a significant capital outlay to replace “splitter boxes” with adjustable headgates. (There are graphics in Wiener presentations to the Climate Prediction Applications Science Workshop and earlier reports to NOAA if this seems mysterious. A splitter box is a flume which has a fin that divides the flow in the desired proportion – allocation literally cast in concrete.)

The third event that threatened farmers was the nearly successful effort by a speculative enterprise to acquire enough of the Fort Lyon Canal shares to change the by-laws and offer a large volume for transfer either out of the Valley or to the far north of the Arkansas drainage, where suburbs outside of Colorado Springs has boomed using unsustainable ground water pumping. The Fort Lyon is still subject to major change by the sales of 21,300 acres (out of 91,300 irrigated acres in good years under the Fort Lyon) now owned by another company waiting to do something. The prior company, High Plains A&M spent roughly $40 million to buy those farms and their water, and was unable to get a change decree without a specified destination for the transfer of water, but it was bought out for roughly $100 million by Pure Cycle; the lesson may be that speculation is very successful (Woodka, 18 Apr 11, Pueblo Chieftain). The Pure Cycle company also joined the Super Ditch as a water rights owner leasing to tenants farming over 15,000 acres, signing up to be eligible to participate. The history of the project is detailed by Nichols (2011, the legal architect and an important figure in Colorado water law and policy for many years), and dozens of articles in the Pueblo Chieftain.

The first two agreements for use of the Super Ditch were announced in late 2009, with the Pikes Peak Regional Water Authority, for the intended price of $500 per acre foot, in the amount of 2000 acre-feet initially with ramp-up to 8,000 acre-feet in a 20 year period (Woodka, 19 Nov 09 Chieftain), announced as a $1 million deal. (That lessee group is headed by Gary Barber, who is chairman of the Arkansas Basin Roundtable, and very active in water issues, as first head of the Fountain Creek Watershed Flood Control and Greenway District, and Manager of the Two Rivers company, which has acquired a damaged reservoir, $9.9 million in state loans for a $30 million project to restore it and resume irrigation of up to 20,000 acres, and water rights by purchase of 90 percent of a ditch south of the Arkansas Valley but in the Arkansas basin, and another restoration project also south of the Valley; Woodka, 22 Feb 11 (two stories) and 24 Sep 11, Pueblo Chieftain). The Super Ditch deal is not yet a contract, but may become one very quickly when another contract is made to convey the water northward using a project not yet built but progressing, the Colorado Springs Southern Delivery System. The second deal waiting to become a contract is with the City of Aurora, east of Denver and booming and sprawling very rapidly before the current economic depression, and expected to resume rapid growth soon. Aurora has moved water out of the Arkansas for many years, in cooperation with Colorado Springs, and bought the Rocky Ford ditch in a controversial major purchase that dried up 8,200 excellent acres with very senior (1861 and 1890) water rights. There have been very complicated arrangements between Valley entities and districts with Aurora, which boil down in one respect to limiting further Aurora purchases, but not leases. The Aurora deal was signed 26 October 2010, also for $500 an acre foot, with variable quantities of up to 10,000 acre-feet in 3 years out of 10 (a limit on certain kinds of substitute water supplies in Colorado law). The Aurora deal is for drought recovery, while the Pikes Peak Regional deal is for base supply (Woodka, 28 Oct 10 Pueblo Chieftain).

In November 2010 more than 600 farmers indicated interest in leasing water to the Super Ditch. A farmer participating will be limited to 35% of her eligible acres in any given year, and the dry-up will be rotating, meaning there will be a limit on the number of consecutive years of partial drying for water transfers (Woodka 20 Nov 10 Pueblo Chieftain). It is also hoped that the contracts will also require adequate cover crops, and allow some irrigation as needed to establish that for both weed control and stubble to capture snow (something we have argued for many years, in the course of these projects, and which seems to have been accepted). This level of interest reflects not only the huge public investments in support of the project, but also significant changes in farmer thinking. And, it reflects surprisingly fast acceptance of the figures determined for how much water is transferable from a share of each particular ditch; that varies considerably as each ditch has a unique historic diversion of water per share, and per acre of irrigated land, and different losses in conveyance and other factors.

This was surprising because the first time there was acceptance of presumptive figures for the consumptive use of water was in the rules for the Arkansas Water Bank Pilot Program. The figures were those from the Kansas vs. Colorado litigation modeling, not usually thought to be as good as possible with current techniques and information, but as the saying goes, “blessed by the Supreme Court”, which did not imply popular approval. Previously, almost any transfer other than a “loan” of irrigation water within a ditch required a case-by-case engineering determination, usually very expensive and contested so that both sides spent a great deal. We participated extensively in interviewing, discussions, public participation, and commenting, as we had been working on transactions cost reduction in Dr. Charles Howe’s efforts for decades, (Howe et al. 1990, Howe and Goemans 2003) and with NOAA funding to Howe and Wiener since 1997 in the Valley. The second acceptance was in the rules affecting sprinkler and drip irrigation systems in the last three year. This was the State response to claims by Kansas that Colorado water use had been expanded, in violation of the Arkansas River Compact and the Supreme Court cases, through the use by farmers of more efficient irrigation which reduces return flows – a claim not accepted by all, but which was thought to require a response. That rule-making was a blow to the Valley farming just beginning to recover from the drought, and very controversial (there is also good Pueblo Chieftain coverage of this issue; it was referred to as “ag efficiency” rule making).

Ninety percent of the Fort Lyon Ditch shareholder have signed up to be eligible for Super Ditch, which may be 90% of 91,300 acres – the Fort Lyon has two major canals, one to supply its reservoirs, and the main canal is 117 miles long, the largest in Colorado. 40% of the High Line shareholders have signed on (the High Line is 87 miles long, and irrigates up to 24,100 acres) (Woodka, 17 Mar 11, Pueblo Chieftain). There are 7 major ditches involved, though not all have yet changed their by-laws to remove ditch company prevention of transferring water out of the ditch. This is widely regarded as an inevitable change, but it might be to allow transfer only through Super Ditch or only through leasing, and the role of the ditch companies may vary quite a bit. There is a gray area in the law surrounding the relative rights of the ditch companies versus their shareholders, which is a complicated story, but the essential point is that it is probably in everyone’s interest to leave that issue foggy and avoid making the ditch companies unable to be involved in leasing arrangements. There are strong collective interests in maintaining ditches, and the necessary conditions of flow, as well as the interests of neighbors who would be badly hurt by lack of weed control or other poor practices. And, from the research side, the ditch companies look to be very important social capital which may allow leadership in re-thinking many pieces of the puzzle in pursuit of something more sustainable and conserving of agricultural production capacity (another story; see Wiener 2011 presentation to Climate Prediction Applications Science Workshop, posted by the meeting and on Wiener website). The ditches are each approaching this in their own ways, (five have amended by-laws, one had rejected that, and one was not settled as of December 2010 (Woodka 17 Dec 10 and 24 Dec 10, Pueblo Chieftain), and have time because of the conveyance issues yet to be settled, including some questions about storage of water in the Bureau of Reclamation’s Pueblo Reservoir, (Woodka 26 Mar 10, Pueblo Chieftain) as well as the use of the Colorado Springs pipeline and pumping system to move water North, roughly along the south-flowing Fountain Creek drainage.

### *Relation to the Bessemer Ditch and the Project*

This is another “good news, bad news” situation. The symbolic significance of the Super Ditch as something showing important progress in both technical analyses, with very substantial investments, and increasing social acceptance is wonderful news from the point of view first developed and advocated in this series of projects, from the literature on transactions costs and the studies 1997 and forward of how to use climate information. This is the fruition of many ideas on leasing, and the mechanism will be climate-responsive by using, judging by the public materials, the concepts of dry-year, average year “firming” and wet-year storage opportunities. These three uses were advocated early in our projects, and argued to the SWSI technical roundtables and basin roundtables. The bad news is that the very substantial publicity and news overage has dominated other ideas that might be relevant to the Arkansas Basin and elsewhere. There is a larger range of ideas in the Colorado program, described in another section here, but the Super Ditch is the great shining hope for alternative transfers and climate-responsive management in the Valley. This is a very strong impression from many meetings and news stories (Pueblo Chieftain, dozens; on file with author and archived by Pueblo Chieftain, e.g. Woodka, 20 January 2011, “Most farmers interested in Super Ditch”).

In practical terms, other ideas are much less interesting while people wait to see how the Super Ditch will play out in the Valley. There was a strong streak of “wait and see” regarding the earlier Water Bank Pilot Program, and there remains a broad view that the Water Bank failed for many reasons without much recognition in the author’s hearing that the design flaws were critical. The general perception seems to be that the whole idea was not wanted, rather than noting that the implementation was driven by situational problems with threats of litigation and much more wide-spread resistance to any change. As the Western Governors’ meeting noted to no disagreement, resistance to any change is still a huge factor, but we find that there may be less resistance now in the Arkansas Valley for three reasons. The first is the set of contextual factors including the Statewide Water Supply Initiative carefully working through the water allocation consequences of urban growth, and the radical increase in acceptance of some defense of agriculture from the business-as-usual scenario of massive increases in buy-and-dry termination of irrigation (see next sections). The second big factor in increasing acceptance of change may be that business-as-usual is proceeding; public disclosure of sales continues (see section on Bessemer Ditch Sales), and it is apparently increasingly appreciated that sales do not have to be disclosed until the buyer seeks a change of time, place or kind of use of the water right acquired. This is a private very competitive market. And the third factor may be that while climate change remains somewhat denied, and climate variation is more accepted but freighted with the politics of denial of real change or human causes, there is no denying the continuing severe dryness in the Southeast of Colorado, generally persistent drought of significant severity since 2002 (U.S. Drought Monitor). The irrigation flows have been fairly good in several years, due to timing and extent of snowpack even while the dryland farming and range conditions have been bad or worse, but that regional drought is very well appreciated (Woodka, 08 APR 2011, “Dry ground, low water concern farmers”, Pueblo Chieftain).

In summary of this interpretation, the problem identification for the researchers has shifted to a much larger set of pieces of the puzzle linked to climate-responsive water management, and the need to work on remedies for other problems which are also necessary but not sufficient, in pursuit of what would be sufficient for progress toward sustainability. But the focus in the region has been narrowed by the relatively huge support for one answer to part of the problem, with the progress of the Super Ditch. The net may be a comforting sense of incremental progress that in the medium term may not be sufficient and in the short term may stabilize some farming but may not support much change. Bessemer Ditch shareholders are interested in the Super Ditch and Dr. Bartolo, Director of the Agricultural Experiment Station in Rocky Ford, is a shareholder who has joined the Super Ditch Board of Directors (Woodka 13 February 2011).

## Colorado's Agricultural Water Alternative Transfers Program – incremental progress

The Super Ditch project is the poster child, with very substantial funding, for a set of projects fostered by the State for several years. There is a detailed report, published May 2011, (Colorado Water Conservation Board 2011b) on this state-funded set of grants to develop different means of transferring water from agriculture to urban uses with reduced adverse impacts on the area of origin and the agriculture in the area.

http://cwcb.state.co.us/LoansGrants/alternative-agricultural-water-transfer-methods-grants/Pages/main.aspx

http://cwcbweblink.state.co.us/weblink/0/doc/150555/Electronic.aspx?searchid=9918b278-0e2f-4c0e-acff-280192b81b95

Because there is such good information available, this report will refer only to the features of the program which are especially important for the context in which the project took place. The project most relevant to the Arkansas Valley of Colorado is widely thought to be the Super Ditch effort, which is described in several documents and sketched in the preceding section here.

What is most important about the Colorado grants program for development of alternative methods of agricultural water transfer is that the set of methods the State has funded are reported as the only set developed in the many years of the SWSI discussions and the technical roundtable on agricultural water transfers, although one of the researchers participated in those discussions and put several additional issues on the table, literally and metaphorically. The progress in funding investigations is real, and better than seemed possible during some of the discussions. But it is still a limited set with limited goals. At the beginning of this set of NOAA-funded projects, it would have seemed miraculous to get this far. In the late 1990s, dozens of formal interviews and informal conversations concerned whether or not there could ever be any change from "buy-and-dry", which was not the term used then for traditional irrigation water transfers. The name was gradually made more popular as public awareness increased, of water issues and of the impacts of transfers on local economies. There is still very little awareness of the severe impacts on soil qualities and the very high costs in productivity losses from the changes in soils. The 19th Century approach to verifying that irrigation had stopped was to require no further irrigation of that ground, so that the "dry" could be observed by anyone. The large sales began in the 1950s, leaving large areas weedy at best and highly eroded often and effectively abandoned in many places gradually aroused some attention, and recently have been attended to more, though still for the socio-economic impacts than the ecological impacts.

What the set of alternatives being considered by the State program lacks is a serious approach to the evaluation of permanent transfers which are partnerships to sustain agriculture, rather than what the state likes to call “soft landing” from municipal purchases which involve leasing the water back to the farming seller for some period of time. In the Bessemer sales to Pueblo, there is a 20 year lease-back in almost all of the sales. This is a way for the farmers to live out their lives and perhaps for their heirs to enjoy the farm for a while, but it is not going to support the kinds of long-term investment and transition to sustainability that would be more desirable.

There is a brief mention of the Aurora Continued Farming Program, (pp 9-10), which is a good start, but has been given little attention. The City of Aurora is a very rapidly expanding former suburb which is now a major part of the Denver Metropolitan area; starting as small suburb, it has increased very quickly and created a major water supply from purchases elsewhere. The purchase of roughly half of the very old Rocky Ford Ditch in the Arkansas Valley aroused great concern in the Valley, and later, when the owners of the “second half” approached Aurora to buy the rest, there was another public outcry. One of the results was increased scrutiny of the re-vegetation requirements imposed on the formerly irrigated lands, and eventually the City began a program on some land in which they left some irrigation water for use with the very expensive but very efficient drip irrigation technology which it financed. This has been the most successful example so far of what can most usefully be called a “partial transfer”, but there is no accepted term yet. The new farming uses only some of the water that was formerly consumed and which could be transferred. The crops grown consume far less water, and the no-longer-consumed part of the water is moved to the urban use. In this example 0.5 acre feet are applied, and 1.26 acre-feet from each acre involved is transferred.

This could be the start of a much better series of outcomes, but the costs have been quite high, and there are a few issues which may be important. First, the cost comes at a time of municipal impoverishment, due to the national fiscal disaster, fiscal and tax policies, and for the non-finance majority of the economy, depression. Will to pay for such projects may not be strong in the future, and this has not been replicated as far as we know. Second, the return flows between the fields and the alluvium and river are eliminated, which has benefits in salinity control but also costs in amenity values, recreational potential, and ecosystem services, which are all not “on the table” because they are not represented by any participants in these transfers. Third, the crops which are grown on the drip systems will have to be high-value fruits and vegetables, to be economically reasonable, and this is a mixed blessing. High-value production is good for the farmers and may be good for the food consumers. But, this reduces the production of cheap livestock feed, which affects the rural and agricultural economies in ways almost entirely ignored so far. The connection between cost-advantaged local feed and the livestock business in the West was pointed out in our comments to the State, and accepted as a concern in recent documents. The sales of livestock are greater than the sales of crops. In 2010, 30.7% of farm sales in Colorado were from corn, wheat, dairy, and hay, while 47.4% were from cattle and calves. Corn and alfalfa are feed crops, with the exception of small amounts of sweet corn for food and corn used for ethanol, and are about 80 percent of irrigated acres in Colorado. So, the scale at which this kind of high-expense program makes sense is hard to consider, and the will to invest in it is also hard to consider and evaluate.

We have proposed research to support and hold a workshop on multi-year crop rotations which would support transitions to more sustainable farming, and begin evaluations of regional integration of multi-enterprise and multi-functional agriculture, because the work reported by the State does not include such efforts.

To summarize the State projects, there are four alternatives being investigated: interruptible supply agreements, rotational fallowing, water banks, and reduced crop consumptive use. The Aurora project just noted is the leading reduced consumptive use project, but others are in progress involving techniques such as deficit irrigation and crop switching.

Our previous work on interruptible supply agreements using climate information has found its way into the discussions in part, as the concept has found acceptance, and the point that these can be useful in dry years, wet years, and average years, for different purposes. But so far, we have not seen an effort to develop the kind of sophisticated partnerships we have recommended. The municipalities have steadfastly insisted that they need permanent transfers of water, ignoring the reality that all water rights in the West are contingent on availability, so it is always a question of the degree of certainty. The cities have not been pushed hard enough to make them look at the big picture, to be blunt, and so we are seeking to get better and better pictures through modeling, but that is contingent on funding. The need for weed and erosion control while not farming is an important issue previously raised in discussions and now being empirically tested by Colorado State University in the Arkansas Valley see section 2.2.5 of Colorado Water Conservation Board 2011 report on Alternative Agricultural Water Transfer Methods Grant Program Summary). Land simply not farmed may require a cover crop or a great deal of herbicide to avoid weed problems which are adverse for adjacent lands as well.

Rotational fallowing is the idea in the famous contracts between the Imperial Irrigation District and the Palo Verde Irrigation District and the Metropolitan Water District in Southern California (Palo Verde Irrigation District, n.d., Nichols 2011). That model was closely followed for the Super Ditch project, described in the next section.

Water banks are highly various in their operations, but all serve to reduce the transactions costs of transfers in some way, and some serve as holding mechanisms for water, also (Clifford et al. 2004). In Colorado, there was an experiment begun in 2003 on which we have reported elsewhere (Wiener 2005). The critical features were not pursued, and the effort was largely deflected into avoiding litigation rather than designing something useful. The project was not litigated, but was also not used and failed. The timing of transactions was delayed to facilitate any possible objection, so that it took too long to move water for very short-term needs, and the duration of allowable transfers was too short for some purposes, so what was available was a product that was not apparently useful and which was not at all well understood. The educational efforts that could be made with the time and funding provided were devoted to allaying fears that this was only another water grab by the cities. The agricultural community was especially clear about both insisting on the right to sell water with no public involvement or interests considered, and also about fearing that it would in fact be sold, in a classic case of individuals needing to keep their options open while publicly arguing that no one should exercise those options. There were other ideas floated for water banking in Colorado, but while the languid discussions drag on, cities have been actively buying water and firming their supplies. The window of need for the major systems may be closing, though the lagging technically unserved small systems will be scrambling for a long time to come.

The other ideas in reducing consumptive use are being taken seriously as ways to make water available, but with the exception of the Aurora Continued Farming Project, and some Colorado State University work with the City of Parker on farms which Parker bought on the South Platte, the possibilities for real partnerships are not being considered. In case this is unknown, “consumptive use” water is the fraction of the water which is diverted to a use and “consumed” by incorporation into plants or products, and evaporation, or in some industrial and commercial uses, rendered unfit for reuse by some pollution. The water law of the West is based on the fact that most uses have a high return flow, which is not consumed, and is available for other appropriations. Agricultural diversions, and return flows, downstream diversions, and return flows, commonly “use” a drop of water five to seven times between the precipitation and the state line in riverine flows. So, when water rights are sold, what can be moved or changed to another use is the part of the water that was consumed. The idea now is that with adequate measurements (or estimations, we would add for the sake of cost-efficiency), farmers should be able to lease or sell some of the historic consumptive use an continue farming with the rest. One technique called “deficit irrigation” has been developed as a response to supply less than demand, particularly in areas where groundwater scarcity or economic scarcity is serious. The plant is given enough irrigation during the critical growth phases to achieve reasonable yields, ideally with less vegetative growth and still good reproductive growth, but not as much water as the plant could use if “fully irrigated”. This is spreading in scarcity areas (see proceedings, Central Plains Irrigation Association), but has not yet been accepted as the basis for a water transfer, largely because of the issues of measurement. It should not be enough, for instance, to have a bad-looking crop; there must be a showing of not using some water to which the irrigator was entitled. Verification in the “gray areas” between “using all you have” and “dry-up” is the obstacle which is getting needed attention now.

A Summary Comment: As these projects are in progress, with the years it takes to accumulate enough seasons and trials to make scientifically defensible claims, the private market moves along. And the larger picture of the many stresses that are steadily washing away the farms is not being considered. We are making some incremental progress in the battle of water, but the war for agricultural sustainability has not been acknowledged by the state as a major policy problem calling for more than occasional lamentation. In Colorado in 1997, 25.3% of cropland was irrigated; by 2007 even with recovery of most of the state from the droughts, only 20.0% of cropland was irrigated. In 1997, 50.7% of Colorado farms had sales less than $10,000, and 96.7% had sales less than $500,000. In 2007, the number with sales less than $10,000 was up to 63.9%, and the percent between $10,000 and $500,000 had dropped from 46% in 1997 to 32% in 2007: this is bifurcation of the agricultural sector; we are losing the middle class of farms that used to support their families! (2011 Colorado Fact Sheet, USDA ERS). Nationally, the very large operations made 84% of sales, while the 16% of sales came from the small farms that still owned 63% of the private agricultural land, in 2003 (Hoppe and Banker 2010). Every state has a government program for agricultural preservation, and there many land trusts and other operations, but we are losing ground very rapidly to conversion to development (Environment Colorado reported on this in 2006), and a great deal of the lost land is the best farm soil, and the most valuable for ecological services. We’re losing the war even as we make some progress in the battle to keep irrigation water available. And then, there’s climate change…

Context for the Project: Because the State has authorized $3 million in grants for the various projects, the discussion has been effectively narrowed to those ideas. There is a "study overload" problem, also, with staff ever harder pressed at the agencies and districts, and now that climate change is being taken seriously by some organizations, that also affects capacity to engage in still more studies. Private interests, however, are indicating increased interest in new ideas, as they realize that the intensity of competition and the stresses on farming are only going to increase. So, although we have had very gratifying agency and district endorsements and willingness to participate in previous projects and proposals, current new work will be sought with the private interests playing a larger role, and with shorter highly targeted projects.

## The New Water Sales from the Bessemer Ditch Case Study Area – Good News or Bad?

One of the most difficult changes for those interested in this project, and advising the researchers, was a fairly unexpected decision by the Pueblo Board of Water Works (PBOWW) to sell a source of trans-basin water diversion, and instead acquire water rights from the Bessemer Ditch shareholders. This was in some ways a favorable development for farming as the PBOWW bought water rights with a 20-year lease-back to farmers according to news reports, and that is preferable to immediately removing the transferable fraction of the water and drying up ground. But the incentives to modernize and invest in new enterprises with a finite term versus ownership are different and smaller. Similarly, the incentives for soil conservation are reduced, where the short-term value of better soil management is as an asset. If there is no long term, the economically rational manager might cut all expenses and investments beyond those needed to manage for exhaustion and degradation at the end of the 20-year term. And a lender might decline to finance anything permanent or in the nature of an investment for the future. There is, however, another view, and this section will try to tell both sides. The executive director of the PBOWW declared to the Interbasin Compact Commission that one goal of the 20-year leaseback was to enable looking for other options to sustain agriculture (Woodka, 01 Sep 11 Pueblo Chieftain).

The psychological impact of the flurry of sales, amounting to 27% of the Bessemer shares still used for farming, is very important, though there is no known scientifically conducted inquiry. The politics of water are permanently so controversial that letters to the editor and such (and in the case of Pueblo, editorials and letters from the active editor!) have been fierce for decades. The regional concern for water losses and dry-up of agriculture has been very strong since the first major sales dried up 50,000 acres in Crowley County, which was still economically suffering from the collapse of the sugar beet and refining industries. In 2010 and 2011 there were also additional purchases of irrigation water from another canal, by a company which employs the Chair of the Arkansas Basin Roundtable (Water Co., which has acquired substantial land and some water rights and a reservoir; Woodka 22 Feb 2011, (two stories); 24 Sep 2011 Pueblo Chieftain).

The importance of the sales from the Bessemer is greater than it might seem. The Valley currently irrigates (as of 2007) about 238,000 acres, but a lot of that is subject to dry-up if purchasers are able to move the water or end lease-backs to farmers. There are 147,000 acres already dried or subject to dry-up according to a recent cumulation by the Pueblo Chieftain

(Woodka, 26 September 2010 Pueblo Chieftain), but there may have been unreported sales, and the Pueblo Board of Water Works continues to negotiate for more shares of the Bessemer Ditch (Woodka, 12 Nov 10 Pueblo Chieftain). The sale of 27 percent of the Bessemer was important for many, not least because of the extremely high quality of the water and land and microclimate combination found there; it is some of the best farmland in the world (Dr. Michael Bartolo, many conversations).

The Bessemer water rights date to 1861 in part, and others to 1864, 1866, 1867, 1870, 1873, 1876, 1881, and 1882, with a very large water right added in 1887 (Abbot 1985). It was associated with the development of Colorado Coal and Iron, which held much of the early shares for use in the railroad rail plant which grew into Colorado Fuel and Iron, famous for the Ludlow Massacre in 1914, when the Rockefellers owned the company, and for being for many years the largest industrial operation west of the Mississippi (Margie Wood story, 08 Aug 05 Pueblo Chieftain has ditch history but does not mention Ludlow). The diversion to the ditch was inundated by Pueblo Reservoir and the Frying Pan-Arkansas Project, so it was replaced by an outflow directly from the reservoir, which means that the water quality is less saline than that used by the other ditches taking water below the confluence of the Fountain Creek. In the Chieftain stories from August 2005, Ms. Wood (water reporter before Chris Woodka) related interviews with the Chairman of the Bessemer Ditch Board of Directors, Bert Hartman, and organic farmer Doug Wiley, on the Bessemer, as the two ends of the spectrum. Her report confirmed our interviews some years earlier, with Mr. Hartman in 1999, and Mr. Wiley after Wiener addressed the Arkansas River Basin Water Forum in 2003. Mr. Hartman's family had been there more than a century, and he felt strongly that farming was on its way out, as a "non-earning asset". Mr. Hartman had also been Cattleman of the Year in Colorado, and was especially informed on the linkages of the feed and cattle businesses. He was also pessimistic about the continuing residential development on the Bessemer; he lived near Avondale, in the middle of the Bessemer. Mr. Hartman sold to Pueblo, and resigned from the Board of the Bessemer Ditch (Woodka 02 Feb 10 Pueblo Chieftain). Mr. Wiley had gone from conventional to mixed organic production, and argued that with specialty products, like his, there was a long future possible – as long as the water was available. His fear was that the ditch could be lost with a majority decision even if some farmers were doing well, and that despite the legal principle that shareholders could hold out and retain their water, in practice it would be very hard. (Indeed, the Rocky Ford Agricultural Experiment Station was a hold-out when the Rocky Ford ditch was sold, and was able to maintain a grip on adequate water perhaps by virtue of being a State agency operation with capable representation and very high community and State value; Michael Bartolo, many conversations.)

It is important for this research that the organics and direct sales – there are many farm stands, and many operations selling vegetables to grocery chains – have been so relatively successful on the Bessemer, though the Listeria problem has hurt many operations. That general success, compared to the commodity and feed production operations in general, confirms the value of pursuing this line of research however possible. (There are no known sources for ditch specific sales information.)

In 2008, the Pueblo Board of Water Works continued its efforts to buy water from the Bessemer, as part of its long-range planning revamped after the shock of 2002. Earlier efforts had been largely rebuffed, but a new effort with higher offers and a 20 year lease-back term was much more successful (Woodka 24 Dec 10, 22 Jan 09, 04 Apr 08 Pueblo Chieftain). By the end of 2009 Pueblo had bought 27% and it was and is willing to buy more (Woodka, 25 Jan 09, 08 Sep 09, 21 Sep 09, 12 Nov 10 Pueblo Chieftain). The Board of Water Works has filed with water court to be able to change the use of the water to municipal (Woodka 16 Feb 11 Pueblo Chieftain). The public information has the price per share at $10,150 per share, far higher than prices paid in recent sales for other water in the Valley; the yield expected to be about 1.25 acre-feet of water per share (and there is no need for new infrastructure for Pueblo to use the water; it would only require putting it into a different pipe very close to the reservoir through which it now flows). A later stories reported the Water Board estimating 1.5 acre-feet per acre yield (Woodka 25 Jan 09, 30 Oct 09 Pueblo Chieftain).

There are important reasons to be pessimistic about the impacts of the lease-back for 20 years which is being used on 99% of the sales from the Bessemer (Woodka 30 Oct 09, 06 Nov 09 Pueblo Chieftain). A lease-back is the term for a sale in which the water is leased to the farmer or her successor for some period of time, allowing farming to continue but with very reduced incentives for investment into the operation, and apparently no incentive for working toward sustainability. The lease-back option in the sales may have been an important incentive (Woodka 30 May 09 Pueblo Chieftain); farmers are known to be seriously committed to farming, but the next generation is facing huge challenges (Hoppe and Banker 2010).

Previous Pueblo purchases of the Booth Orchard ditch and other water resulted in dry-up of the land. Dr. Bartolo said, "…they are not buying a chunk of a ditch, but are destroying the autonomy of it… They are destroying the value of the Bessemer Ditch." (Woodka 02 May 09 Pueblo Chieftain).

" 'I don't think there's any question that the Bessemer Ditch needs to form some sort of municipal partnership," Bartolo said. "We need to pursue something that is anchored in the community. The true value of the ditch is not that piece of paper that represents stock, but the autonomy of the ditch. The municipalities use that against us.' " (Woodka 02 May 09 Pueblo Chieftain). That was as good a statement as any for the rationale for this project and the very difficult situation in which we were both inspired and frustrated, being a footnote to the huge impacts of the big changes in the Valley.

But there is another side to the story which may turn out to be important: the Pueblo Board of Water Works and its Director, Alan Hamel (a very widely respected leader in Colorado water issues, and the first Chair of the Arkansas Basin Roundtable by acclamation until his resignation) have affirmed that part of their motivation was to prevent other cities from buying parts of the Bessemer (Woodka 04 Apr 08, 22 Jan 09, 10 Jul 09). Mr. Hamel has stated that many of the farmers selling and taking the lease-back option said they were very pleased to be able to continue farming, and to be able to buy new equipment (Woodka 14 Oct 09 Pueblo Chieftain).

Dr. Bartolo mentioned this project as one the ways to explore new crop mixes and different management of the ditch in an interview with Chris Woodka of the Pueblo Chieftain, reported 13 Feb 10: "In fact, on Friday he was exploring new ideas with experts from the University of Colorado and Natural Resources Conservation Service, using computer models developed by David Yates of the National Center for Atmospheric Research a Boulder that help water users cope with changing climate conditions."

“Using the models, which broadly project effects under uncertain conditions, Bartolo wants to find out if the crop mix on the Bessemer could be changed in the future to benefit Pueblo.

“We’re looking at what happens when change the crop mix. For instance, growing canola to make biodiesel for the Pueblo transportation system,”, Bartolo said. “We’ve got to have alternatives to prevent buy-and-dry, and look at new partnerships. The city could look at the ag industry as getting a new Vestas [manufacturing] plant. It could have that kind of economic impact.”

“In other words, the water would not only aid industrial growth, but could be its own kind of growth.

“There is also the issue of producing food locally.

“ ‘Really, we could buy a lot more food from the valley more easily, rather than trucking everything in from 2,000 miles away,” Bartolo said.

Bartolo isn’t sure where the research will lead yet, but he’s hoping to develop some information about alternatives that could help shape future decisions on how to use the water in the next few months.

“The Pueblo water board is receptive to the idea of new uses for Bessemer Ditch water, said Alan Hamel, executive director.

“ ‘I think we’re always hoping and looking to different options in the future,’ Hamel said. ‘We’re open to looking at other ideas.’ “

On the 17th of February, 2010, a Pueblo Chieftain editorial urged new ag – and the fact that agricultural evolution is nothing new. Biofuels were mentioned.

On April 4, 2010, Dr. Bartolo wrote a story on the value of the Bessemer farming as an incomparable community asset, and described the very large diurnal temperature variation which supports the excellent fruit and vegetable quality, along with the high water quality and good soils. A conservative estimate is that an acre of Bessemer farming creates over $1,000 of sales per year in what should be a sustainable industry that will always have demand and has high local economic multipliers.

Meanwhile, as part of the Super Ditch studies economic impact of transfers work investigated “tipping points” in local economies from water sales and lost farming, in work reported to the Lower Arkansas Valley Water Conservancy District in July (Woodka 25 Jul 10 Pueblo Chieftain, and p.c. Dr. Ken Weber). The economics of major losses include loss of local retail and increased “leakage” to shopping elsewhere, losses of services, and increased off-farm employment for those who remain, though this is difficult to evaluate because so many “farms” have minimal sales needed to qualify the property for agricultural tax rates. The discussion also noted the Arkansas Basin Roundtable’s Considerations for Agriculture to Urban Water Transfers report as the source of pertinent questions and answers. Wiener was advisor to the subcommittee which met for two years and developed that document (again, thanks to NOAA funding which made it possible to make that contribution as part of work on this series of projects).

Where water management has been more forward-looking, as on the High Line, there have been some new farmers despite all the odds against them, and some very persistent families that want to stay in the business. The High Line continues to work on leasing programs, perhaps with additional stimulation from Woodmoor's purchase of several farms, and the pursuit of a decree to make exchange rights permanent which would facilitate moving that water (Woodka 23 Aug 10 Pueblo Chieftain).

### *Where is the Bessemer now?*

On the one hand, the Pueblo Board of Water Works has invested in both improved water measurement on the ditch, and the water court decree to change the use of water to municipal. And it is still offering $10,150 per share for more of the Bessemer (Woodka 16 Feb 11 Pueblo Chieftain). On the other hand, "We included a 20-year lease-back so we could work on other options to sustain agriculture," said Alan Hamel to the Interbasin Compact Committee (Woodka 01 Sep 11 Pueblo Chieftain). "We think we can go even longer than 20 years and work out other options", said Hamel. Pueblo now owns 28% of the Bessemer. Hamel said that agriculture would be retained as a use on all of the shares. "We have the opportunity to sustain agriculture in our community."

Offers to buy water continue; doubtless, most are not public knowledge, and contracts that are signed are not necessarily disclosed until the buyer has to file with water court to change the use. Woodmoor, a suburb of Colorado Springs, has offered $4300 per acre for High Line Canal water (Woodka 21 Jan 10 Pueblo Chieftain), and has also made offers on the Holbrook Canal. This was made known when Woodmoor filed for an exchange decree, which is a water court decree allowing water owners to trade up and down a river, to enable easier moving of the water. Financial aspects of exchanges are not public. There are often complaints based on the removal of cleaner upstream water and its replacement by lower quality downstream water, but historically the water courts have not been authorized to consider that, and although they now can, it is not clear whether there will be any impact, as such complaints have been traditionally countered by proponents usually far better funded (this claim is based on attendance at years of meetings by Wiener).

## The Listeria Disaster and the short-term versus the long-term

In June 2011, two cases of listeriosis were reported, called listeria (Listeria monocytogenes) in the press. This bacterium is ubiquitous in soils in Eastern Colorado and elsewhere, but in sufficient numbers it can fatally infect people (usually in a compromised condition). The reports of cases continued over the summer, and in August another nine infections were reported. In early September, melon was identified as the likely source in Colorado and elsewhere. A few days later, Rocky Ford melons were identified in the multi-state outbreak. Grocery chains pulled melons from their shelves in at least five states. The regional identification was very damaging to the Arkansas Valley, home of the melon cultivar named for Rocky Ford. Although it was only a few days more before a single farm 90 miles east of Rocky Ford was identified as the source of danger, the tremendous negative publicity hurt direct sales of other vegetable produce as well as wholesale losses. The publicity was so negative that there were serious losses in California, too, where unsalable melons were not worth harvesting. By the time the single farm was identified, the season was over, and farming leaders predicted dramatic decreases in the amount of planting next year, with switching to lower valued crops. Agricultural researchers and agency staff were tasked with fast responses to the developing situation, and ad hoc rapid testing programs were expanded into larger efforts. The latest front page story in the Denver Post was on the first of December, in a long stream of very adverse publicity.

Cantaloupe is primarily produced elsewhere in the U.S., but is a "signature" product for the Arkansas Valley. See "charts of note" on the USDA ERS Website. ERS estimates that Colorado in 2010 had $7,984,000 sales from 2,200 harvested acres. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1478 Released 07 Jun 2011 (ERS new information).

The losses to irrigated farming vegetable and horticultural products are not yet known, but it is very unfortunate that this took place while severe drought conditions in the Southeast of Colorado persist, hurting dryland crops and worsening long-lived soil moisture deficits. The irrigators using a relatively good snowpack in the southern mountains, though not as good as the old normal, were enjoying a good supply and good imports of "project" water into the Frying Pan-Arkansas Project, (Woodka, 28 April 2011) and high prices for corn and feed. (A selection of news stories from the Denver Post is included as an appendix to this report; regarding the drought conditions, see U.S. Drought Monitor; for information on prices, see Economic Research Service, U.S. Department of Agriculture, particularly including the farm income "briefing room" website.)

The intended set of interviews and discussions on this particular project were not held in these last few months while these conditions took center stage, and the continuing headlines held attention on the short-term problems and responses. After letting things settle while the Bessemer water sales and some other regionally important water deals were announced, including yet another proposal to export a large amount of water from the Valley to the Denver Metropolitan area, and for natural gas purposes, this was deeply frustrating for the project.

## Bessemer Environment

The physical environment of the Bessemer Ditch and much of the area are well described by the Natural Resources Conservation Service (2001, 2007), and the area has been studied by the Colorado Natural Heritage Program as well (2003). Thus, this report will only mention a few highlights. The watershed study for conservation planning for the Six Mile-Saint Charles Watershed included 36,480 acres, of which 20,000 have been irrigated by the Bessemer, of 22,785 acres of crop land. There were 5,023 acres of riparian and wetland areas, along the drainages and the Arkansas River, giving the area high potential for continuing conservation. 7,922 Acres were residential/commercial and miscellaneous (e.g. the water treatment facilities of the Saint Charles Mesa Water District, and a large cemetery). The land is 98% private. There were as of 2001, 500 farms with an average size of 40 acres, and 20,507 acres of prime farmland (2001 NRCS). But, 99% of the soils are highly erodible.

We add that there are three distinctive areas of the Bessemer: the Blende area, on the West, which includes many small parcels and residences, many dating back to prosperous savers who were able to earn enough in the steel mill and shops and mines to own land and garden intensively. The area has some dilapidated housing, but also some very attractive places and a neighborhood character which eases into more open space and larger parcels, with more recent development as one proceeds eastward. The Salt Creek is the western edge of the Bessemer, and the Blende area is bordered by the Saint Charles. The Blende area will almost certainly become “gentrified” further and would be benefitted by better recreational access, and Pueblo County and the City are working on that.

The middle area, between the Saint Charles and the Six Mile Creek, has much larger parcels, for the most part, and is an area of collision between residential development in clusters and individual lots eating away at the farmland. (See figure, “Nobody in the Driver’s Seat”.) This area is effectively about as close to Pueblo as the Blende area, in terms of motor vehicle travel, since it has access to Highway 50 to the north by a bridge and busy road across the Arkansas. This area is at high risk of continuing perforation and agricultural discouragement by the classic problems of people wanting the amenity value and open space and yet not wanting the noise, odors, farm vehicles, and not wanting to expose themselves to the chemicals in use. These conflicts are widely understood and yet, as the Esseks et al. 2009 study reported, hardly solved or in some places little reduced at all by “right to farm” laws or ordinances, or other efforts. This area can be called the Vineland area, after the commercial center on Business 50.

The eastern area, between the Six Mile Creek and the edge of the mesa where it drops down into the Huerfano River bottomlands, can be called Avondale, after the commercial center on that end of the ditch, also on Business 50, the old highway. This part has much larger farms, in general, though still not very big, and relatively fewer carved-out parcels for residences, but some are glaringly large, and new, and there are several dozen along the easier roads. Access to the highway and across the River is by a new bridge on one road, an older one north of Avondale, and east or west along the old highway. This is the most commercial farming area, and has the largest share in large parcels not yet broken up. We located the new urban development, the receiving area for transferred development rights in our recommendation, near Avondale, as described below.

We also recommend increasing the size of the wetlands at the headwaters, so to speak, of the Six Mile Creek to take advantage of some odd-shaped parcels and the chance to extend existing wetlands which are relatively “natural”. It is important in this situation that the Six Mile catchment is small, south of the Bessemer, and that for three years running it was impossible to discern from the public road (on this private property) any signs of surface water; the drainage was occasionally inferred from the terrain and at some times greener vegetation or taller vegetation. The inflows to Six Mile are very largely, except in ephemeral runoff events, seepage from the Bessemer. Therefore, it seems appropriate that this be turned to advantage if there is any market now or if there will be a market, for wetlands banking or credits that are transferable. Such markets have existed, and depend on unfortunately politically set criteria for the jurisdiction of wetlands (Wetlands 2003; Environmental Integrity Project 2005), and the extent to which policy and the scarcity of wetlands affects the market. We expect that two factors will become relevant along the Lower Arkansas. First, climate change and the persistent drought conditions are likely to affect riparian and wetlands conditions from changes in precipitation, especially affecting the small drainages where inflows are not added from irrigation. This is a radically modified hybrid ecology (Wiener, Yates et al. 2008). And second, there are changes in the irrigation contributions to wetlands. There are increasing investments in reduction of canal and ditch seepage, to increase efficiency of agricultural water use, and increasing use of center pivots and even some drip irrigation to increase efficiency of the old flood and furrow irrigation. These changes reduce the return flows to the River, which currently supports vegetation not benefitted by the controlled mainstem flows. Return flows in the river may not be modified by irrigators, but when water is transferred or the use is otherwise changed, the requirement is not to continue watering the intervening area between former places of application and the river, but to leave flows which will be administered to maintain the historic pattern – in the river (Wiener, Yates et al. 2008). If there is anything like a "no net loss of wetlands" policy, being able to "create" new areas may be lucrative. In the Bessemer area there were 336 acres of Palustrine emergent wetlands, 260 acres on open water, and 3,881 acres of Palustrine Scrub, shrub, and forested wetlands – the riparian areas. We recommend conservation areas along the drainages to maintain that and eventually remove some development.

These areas relate to another benefit that may arrive in the event of threatened or endangered species issues in the Valley. The Bessemer and its surrounding area support or may support Black Footed Ferret, Bald Eagle, Swift Fox, Mountain Plover (proposed as threatened), Colorado Butterfly Plant (proposed as threatened), Arkansas Darter, Black-tailed Prairie Dog, Whooping Crane, Western Burrowing Owl, Flathead Chub, and American Peregrine Falcon (NRCS 2001, 2007). The Colorado Natural Heritage Program (2003) described the ecology of Pueblo County and the wetlands conditions, increasing recreational uses, bank stabilization problems, invasive species, fragmentation and edge effects problems, and revegetation problems. Twelve kinds of wetted/wet lands were distinguished. The Six Mile Creek potential conservation area was of moderate significance. Dryland areas south of the Bessemer and north of the Arkansas River have higher significance partly because of size of areas. But, the Six Mile Creek area has value because of its connection between the Huerfano Uplands area and the River, and thus to many other areas. Six Mile water sources are not well understood, but it is habitat for the Arkansas Darter and could be better for that. It was noted as a good site for environmental enhancement.

We suspect that the future will bring additional stress on species of interest, with both hydrologic and climate changes, and continuing land use changes and fragmentation/perforation of habitat. It may be very useful, therefore, to defend against future problems by assuring habitat conservation, and taking advantage quite explicitly of the fact that there is no "natural" land to be regarded as pristine. Rather, this is all modified, and so we suggest that there can be mixed uses as we have mapped, in which recreational and amenity values are increased, habitat values are maintained and can be improved with gradual work on invasive species (particularly along the Saint Charles), and improved function as corridors and connectors. Private interests may be involved, as one land conserving project has been announced (Palmer Land Trust n.d.). It is hoped that there will be synergy of these interests supporting long-term improvements in the ecological functions along with the capture of value from the amenity and recreational opportunities from improving the conservation areas (see illustrations).

There may be significant strategic advantages for the long-term management of the Bessemer in establishing the conservation areas with suitable management and transitions toward intended functions as a Habitat Conservation Plan (U.S. Department of the Interior etc. 1996, 2000, Taylor and Doremus 2011). Under present policy and law, this would provide considerable security against threatened or endangered species issues in the future. That higher level of certainty should add value to potential wetlands mitigation projects and support long-term planning and transitional management as well as recreational benefits.

There are also water quality benefits from increasing the functions of buffer areas between irrigated agriculture and erosion, water management and water quality were among the top concerns for the Bessemer area (NRCS 2001 and 2007). The watershed study was done for a program that involved 13,000 acres – about 60% of the irrigated land – and 250 long-term contracts, with about $7.3 million in the program (NRCS 2007). One motivation was the concern over salinity, nitrates, and selenium (the Huerfano River is impaired (303(d) listing) because of high selenium). It is notable that salinity farther down the Arkansas is dramatically high, well over limits for recommended uses including cattle watering, and requiring substantial treatment for human use (Burkhalter and Gates 2005, Gates et al. 2006). That situation is also the motivation for the Arkansas Valley Conduit, which was part of the original designs for the Frying Pan-Arkansas Project, and may finally be realized; it will be a pipeline to carry good quality water from the Pueblo Reservoir to towns downstream along the salty river, at considerable expense (there is extensive coverage in the Pueblo Chieftain which has searchable on-line archives).

Although the water quality going into the Bessemer is excellent, coming from Pueblo Reservoir, there may be benefits from minimizing reductions in water quality in the return flows to the Arkansas. There may be no economic benefit unless there is a regulatory program imposed, but there is a lurking threat (this is Wiener's opinion, not necessarily Yates and not that of the University of Colorado, National Center for Atmospheric Research). Kansas has rights to flows in the Arkansas River, which have so far been regarded as rights to water quantity rather than quality (see Robbins and Montgomery 2001, and MacDonnell 1999). The water quality at the time of the Arkansas River Compact was poor or worse, but it can be argued that there has probably been substantial worsening. The regulation of flow by the reservoirs has included also steadily and hugely increasing municipal effluent flows which are in part (the indoor use) constant, a condition which is quite unnatural and which increases the alluvial flows as well as the surface flows, and therefore increases dissolution of salts from whatever saline shales (this is members of the Pierre Shales) are exposed to the flows, and exposes those salt sources to water quality which may have chemically altered character compared to un-used snowmelt pulses. Increases in irrigation have been strictly controlled since the Kansas v. Colorado litigation and its aftermath, but the same concerns about duration of exposure of salt sources may apply. Increasing acidity of precipitation from global and regional conditions may have an impact, though this is not known; there are studies showing impacts of regional conditions farther north (Strange et al. 1999; Baron et al. 1998, 2004).

The salinity conditions and their political and ecological importance may be affected by not only climate change and increasing frequency of droughts but also by increasing runoff from high intensity precipitation and cumulative impacts on range conditions; this is also Wiener speculation based on Climate Change Science Program 2008 reports. The political significance may be in the imposition of a Total Maximum Daily Load (TMDL) limit on salinity, affecting changes in use. In the event of a TMDL there may arise a trading situation and "created benefits" from improvements on the Bessemer may have some value. More likely, it may be useful to be able to show that irrigation is not adding to the problem. Whether Kansas could impose water quality standards is an open question, but as conditions change – especially with decreased flows due to municipal capture of transbasin water currently donated to the river – and as forecast for climate change, it seems unlikely that this would not be considered.

Water transfers from the Valley, according to an analysis by the Pueblo Chieftain (Woodka 2010) may cumulate, from already legally final sales, to one third of the formerly and presently irrigated acreage, but there is no cumulative impact analysis required in any of the legal or regulatory processes. Substantial sales have not yet resulted in removal of the water, due to delay of some plans, failure of a few, and purchases in anticipation of needs. There are good reasons, from the buyer's perspective, to anticipate both increased scarcity of high-priority/senior water rights, and to buy water at lower rather than higher prices. From the perspective of agricultural management, however, insecure water supply, even with a term of "lease-back" up to 20 years, may be destructive of both the incentive to innovate and modernize, and the capacity to finance change even if wanted.

Finally, it should be noted that the full costs of revegetation of formerly irrigated lands dried up due to water transfers are still not a matter of public disclosure, but are known from the experience of efforts by the City of Aurora on the Rocky Ford Ditch, to be non-trivial, though their relative costs given the increasing value of the water may be decreasing. Dr. Sutherland (1992, 2004) has monitored progress on behalf of several interests and the Natural Resource Conservation Service, and has also very generously advised this project and its precursors. He has communicated that the costs were surprising, but that knowledge has increased and that it is likely that the duration of efforts needed may be shorter with that experience and that it may be easier if decrees and agreements specify that some irrigation to establish revegetation will be planned. We add that this should also include flexibility to respond to unusual conditions. The open question may be how much economic value such lands can have with management for invasive species control under climate change and high variability; perhaps long-term management can provide useful grazing under some conditions (not yet known to be investigated). Revegetation requirements have been imposed on recent water transfers, but were not imposed on the great majority of transfers before the late 1980s; the first serious requirement may have been for the Rocky Ford Ditch transfers. Crowley County was largely dewatered long before such requirements, but transfers from areas sold before requirements but not accomplished yet might be subject to public pressure though it is a significant cost. Revegetation of dried lands is apparently part of the recent agreements between Denver Water and the West Slope Colorado River District and others (Denver Water Board 2011), and it is likely that further research on techniques is forthcoming, but how revegetation will interact with climate change and its consequences may complicate the efforts.

# Corn, Ethanol, and Biofuels

## *Against Corn*

Bluntly put, U.S. corn (maize) with high-input and high tillage production is a loss of energy and resources (Patzek 2008), in terms of soil and thermodynamics. It has been heavily subsidized by the lack of externality costs charged for its production pollution and impacts (like other major crops), the subsidies from fossil fuel production and uses, not charged for their externalities in production pollution and impacts, and often produced with access costs based in politics, and by transportation subsidies for everything from the railroads to the barges and the highways, also not charged for negative impacts. The question is not how to sustain enormous levels of corn production, but how to sustain the producers and the productivity of the land.

Monocultural maize is not sustainable even with no-till; the lower erosion of no-till is accompanied by high inputs and chemical and biological soil degradation. Unsustainability of average U.S. maize field is high; it takes 6-13 times more energy to reverse soil erosion and degradation, etc. than the direct energy inputs to maize. Maize [and other annuals; Jackson 2010] are grown by enforcing a perpetuated pioneer stage of secondary succession, requiring constant push-back against ecological tendencies toward nutrient capture in diverse communities (Patzek 2008, Patzek and Pimentel 2006; see also Magdoff 2007). "It may be argued (Loomis and Connor, 1992) that the single largest factor behind the 7-fold increase of maize yield over the last 100 years has been nitrogen fertilizer, followed by genetic gains, plant density, herbicides, and machinery. The decreasing factors have been less manure, less organic matter, erosion, insects, and crop rotations. It also follows that all easy genetic gains may have been already achieved with maize, as well as most other major crops." Patzek 2008: 277). There has been steady gain in efficiency in the developed world of adding N fertilizer in terms of N added/kg of yield, but there is emerging evidence of soil acidification from steady additions of N and changes in decompositional processes that can reduce soil organic carbon even with incorporation of residues (Patzek 2008). How climate change will interact with these changes in soil biota is not clear but may be significant. Patzek made his calculations using information on Iowa and other soil erosion rates which unfortunately may be lower than reality. The Environmental Working Group (2011) has recently reported on findings from monitoring fields rather than modeling, and the results are shocking. Patzek also argued that the longer we delay transition from massive corn production to more sustainable crops and practices, the larger will be the losses and the higher the costs imposed.

U.S. corn in 2001 used more than 40% of commercial fertilizer in US, and cornfields are subject to significant erosion and runoff causing contamination of surface-water drinking supplies and degrade aquatic habitats (Hopkins and Johansson 2004). Corn growers manage nitrogen quite poorly, owing to the incentives to apply enough to meet all possible needs if the weather is ideal, and the minimal costs of poor management of applications, and the zero costs to the farmer of pollution (Ribaudo et al. 2011 p 11-13). The General Accounting Office (2009) reported on the linkage of concerns with corn production pollution and increased production for ethanol. As noted in the discussion of conservation tillage, there may be a trade-off in substituting increased herbicides for decreased tillage; the fate of contaminants is insufficiently known, but there are serious concerns about environmental impacts (National Research Council 2010b, Gilliom et al. 2006). The USDA and others have stated policies to reduce N and P loadings into the

Mississippi Basin (which includes the Arkansas River basin), (Alexander et al. 2008; General Accounting Office 2009: 10) but as Lemke (2010) emphasizes, the policy is also that reductions in pollution will have to be voluntary.

In USDA data for 2006, two-thirds of U.S. cropped acres treated with N were not managed according to criteria for efficiency of use. Over two-thirds of U.S. major crop acres, or 167 million acres, are treated with N as commercial or manure nitrogen, and 108 million acres need better management. Meanwhile, 97 percent of corn acres in 2005 received Government payments, averaging $51.39 per acre. EQIP program payments for adoption of nutrient best management practices averaged, on far fewer acres, $8.88 per acre (Ribaudo et al. 2011).

Beyond consumer spending of an estimate $800 million per year for bottled water to avoid nutrient-related taste and odor problems, USDA ERS estimates $4.8 Billion per year spent on nitrate removal in drinking water; of that, they estimate $1.7 Billion per year to be agriculture's share. But we lack estimates of the costs of other environmental impacts, or the cumulative and synergistic impacts of eutrophication and water quality degradation with other pollution Ribaudo et al. 2011). "Corn is the most intensive user of nitrogen and the most widely planted crop. Improvements in rate, timing, and/or application method are needed on 70 percent of corn acres to improve [nitrogen use efficiency] NUE. In addition, growth in corn demand due to the biofuels mandate suggests that corn acreage may increase in the future, along with the intensity of corn production. Together, these factors could increase reactive nitrogen emissions to the environment unless nitrogen use efficiency is improved." (Ribaudo et al. 2011 pp 17-18.) Among all U.S. field crops planted in 2006 that received nitrogen fertilizers, 35 percent are estimated to have met all three of the nutrient BMPs. For the remaining cropland, improvements in management are needed to increase nitrogen use efficiency (i.e., reduce the amount of nitrogen available for loss to the environment)… Corn is the most intensive user of nitrogen fertilizer, on a per acre basis and in total use. Fertilizer applied to corn is least likely to be applied in accordance with all three BMPs (Ribaudo et al. 2011).

Vegetative buffers can be effective for removal of nitrogen heading off-farm (Ribaudo et al. 2011; a large literature denitrification processes and buffer strips; Schepers and Raun 2008). Nelson et al. 2006, modeled the use of switchgrass as a water quality benefactor in buffer strips and as alternative energy source. Figures may not be useful now, but showed the sensitivity of the results of N use, a high proportion of cost of production where used, and the ease of exploration of potential combination of uses. This is relevant to the Bessemer because of the availability of large buffer areas in the drainage creeks if they can be suitably managed and flow into them is suitably managed. The trails network should be managed as buffer strips where appropriate, for run-off management as well as aesthetics/amenity and recreational value. Wetlands are also effective filtration, and should be managed for this purpose. The "new" expanded wetlands proposed on the South-east, on the Six Mile Creek, would serve as an expanded reservoir of vegetation for eventual transplanting to other areas if carefully managed to reduce invasive species. The location at the intersection of the Bessemer Ditch and the Six Mile Creek reflects opportunity and current uses, and serves to facilitate a somewhat modified flow regime in the Six Mile if the expanded wetlands area acts as a lag in return flows, perhaps increasing late season wetness in the affected area. But, the use of water for large amounts of corn may be questionable on other grounds; we need to know more about transitions and about multi-year crop rotations. There are about 5,000 acres of corn on the Bessemer as of 2003, but that figure could vary substantially; the limitation is water rather than soil quality.

It is also important for the economics of the Bessemer in particular and any planning longer than a few years to note that the oligarchic structure of the rest of agriculture also applies to fertilizers. There are very few firms producing N in the US, or P and K, and imports are increasing, and as with oil, from governments not necessarily oriented to sustainability or US well-being (Huang 2009). The instability of prices must be considered in any long-term thinking.

## *Ethanol*

It is highly unlikely that large scale (10% of transport fuel mix) biofuels production can be sustainable by 2020 according to government criteria for many nations. From 2001 to 2007, world ethanol almost tripled, and world biodiesel increased five-fold, but food riots in 2007 and 2008 and a large increase in hunger raised concerns which led to the development of sustainability criteria in the European Union. Bindraban et al. 2009 found that current promotional policy seems unwise given the land needed and the likely land conversion effects. In the U.S., sustainability criteria have not been adopted, but there is increasing concern outside of some groups (United Kingdom 2011, National Research Council 2010b, McIntyre, Ed., 2009). The land conversions to ethanol production vary in their net impacts because the previous uses affect the impact (General Accounting Office 2009, Schimmelpfennig et al. 2011).

"Corn is a heavy user of nitrogen fertilizer. Given the RFS targets, the resulting increase in fertilizer use and shift from corn-soybean rotations to continuous corn production leads to deterioration of key environmental performance measures. Nitrogen losses to surface water and groundwater increase by 1.7 and 2.8 percent, respectively, while soil runoff increases by 1.6 percent from the baseline. Differences in geography, soil type, and prevailing agricultural production activities lead to considerable variation in environmental effects among regions. The increases in leaching to groundwater are greatest in the Lake States and Southeast, while increases in runoff to surface water are greatest in the Corn Belt and Northern Plains." (Malcolm et al. 2009: iv).

"The recent 9-billion-gallon increase in corn-based ethanol production, which resulted from a combination of rising gasoline prices and a suite of Federal bioenergy policies, provides evidence of how farmers altered their land-use decisions in response to increased demand for corn. As some forecasts had suggested, corn acreage increased mostly on farms that previously specialized in soybeans. Other farms, however, offset this shift by expanding soybean production. Farm-level data reveal that the simultaneous net expansion of corn and soybean acreage resulted from a reduction in cotton acreage, a shift from uncultivated hay to cropland, and the expansion of double cropping (consecutively producing two crops of either like or unlike commodities on the same land within the same year)." (Wallander et al. 2011: abstract.)

"As annual U.S. ethanol production increased 9 billion gallons between 2000 and 2009, demand for the feedstock used to produce ethanol also increased. In the United States, corn is the primary feedstock for ethanol production, and harvested corn acreage increased by roughly 10 percent (7.2 million acres) over the same period, with much of the change occurring in 2006-08." (Wallander et al. 2011: p iii.) "Between 2000 and 2009, U.S. ethanol production increased from

1.6 billion gallons to 10.8 billion gallons (U.S. Department of Energy, 2010). Over the same period, U.S. corn production increased from 9.9 billion bushels to 13.1 billion bushels, while harvested corn increased from 72.4 million acres to 79.6 million acres (USDA, National Agricultural Statistics Service, 2010)." (Wallander et al. 2011: p 1.)

There was significant crop switching or increases in double cropping or both in the Arkansas Valley of Colorado during 2006-2008 (Wallander et al. 2011: 7 and Schimmelpfennig et al. 2011 map county data). We are using 2003 public GIS data from the State of Colorado for this project, but we suspect that the corn acreage from that time has been increased substantially.

Increasing biofuels' demand for feedstocks may result in increased use of nutrients and pesticides as cultivated land and corn acreage expand. Average rates of nitrogen use in U.S. corn production (138 pounds/acre) (USDA-NASS, 2006), for example, are greater than application rates for crops that may be displaced—including soybeans and wheat (16 and 66 pounds/acre, respectively) (USDA-NASS, 2007). Pesticide use also tends to be relatively intensive in U.S. corn production. Higher prices for corn and other crops may also increase the intensity of chemical input use." (Malcolm et al. 2009: 9.) USDA modeling of crop inputs, acreage, and runoff and erosion showed that increased corn production for increased ethanol has effects on water quality which are greater than might be the case for increased production of other crops which are likely to be displaced by the switch to corn (Malcolm et al. 2009).

It must be noted that the USDA work almost always simply does not incorporate climate change, impacts of climate change, and the already-observed increasing intensity of precipitation. The Soil and Water Conservation Society argued in 2003 that the precipitation quality change could alone reverse all of the progress in soil erosion reduction since the 1930s. This is apparently confirmed by the Environmental Working Group (2011) close monitoring of fields in Iowa, and the dismal contrast of their findings from the empirical study (in association with Iowa State University) with the conventional estimates of erosion.

The US General Accounting Office (2009) affirmed other information that environmental impacts of biofuels are so far thought to be the impacts of the feedstock production, with most concern over the corn for ethanol which dominates the biofuels sector and which is input-intensive, so that the range of negative impacts from high levels of N, P and biocide applications and run-off, and soil erosion from intensive cultivation in conventional tillage, and increased erosion from conversion of marginal land to intensive cropping. The latter is of particular concern for the CRP lands which were bought out of intensive use for conservation purposes, and which were the highly erodible lands and other marginally-productive lands (most recently, see Schimmelpfennig et al. 2011).

The other huge environmental issue with biofuels is changes in water use. The feedstock crops are being studied for increased production and presumably lower water needs or drought resistance, but what is seen as new is the large potential increase in irrigation applied, due to the large forecasted increases in acreage for corn in particular. (ERS 2008 figures indicate forecast increases of about 1.5 million acres in the Northern Plains, as well as similar increases in corn acreage in the Corn Belt and similar increases in the other regions considered, but the patterns of land use change have been complex (Schimmelpfennig et al. 2011).

A gallon of ethanol from corn, using recent technology, takes less water than when the technology was first operational, but the USDA is cited for estimation that a gallon of ethanol from NE and KS takes about 323 gallons of water for the complete process of seed to feedstock to fuel. The conversion process itself takes about 3 gallons of water for a gallon of fuel (GAO 2009). In contrast, biodiesel refining takes a little more than one gallon of water per gallon of fuel or about two gallons (Oregon Environmental Council 2007). Water used in the ethanol production is apparently almost all consumed in cooling and processes.

Timing of water demands is potentially an important benefit of allocating some acreage to oilseeds, because their peak demands are earlier in the year than those for corn (Helm and Johnson 2008). The total water demands for oilseeds are also lower than those for corn. This may be an additional advantage for biodiesel since the value of the water is affected by availability of storage or not. If the irrigator takes water whenever it is available (is "in priority" and cannot time application), there may be water being applied to alfalfa or pasture/feed/grazer crops that therefore have lower return (on the water as an input to production) than if applied to oilseeds. The timing issue may also be of interest because of shifting seasonality in the available flows, due to climate change and variation in snowpack melting; earlier-water demanding crops may be more desirable as part of rotations which are designed for shifted seasonality

## *Biodiesel and Winter Canola*

The scenarios modeled include winter canola for biodiesel, though it would be good to have more information on the whole life-cycle of growing, processing, feeding the co-products, the glycerin by-product from some feedstocks, and the use and sales of the fuel. It is critical in this idea that the stability of self-fueling for farmers, multifunctional multi-enterprise operations, and city partners is a very important benefit. If the inputs are limited, seed is normal rather than annually re-purchased, rotations are well designed, and the water use is as expected, it should be possible to produce diesel on a predictable basis with a predictable cost. This may make the fuel especially useful for long-term contract sales or as a product of a partnership. In this case, it would be the City of Pueblo and likely the two large school districts in partnership with the Bessemer. We want to acknowledge that this idea was suggested by Dr. Lorenz Sutherland, who has been a very thoughtful and generous advisor to this and previous projects. There are trials underway in the Arkansas Valley for Winter Canola, testing cultivars and yields and water demands, some operated by Dr. Michael Bartolo, another enormous contributor to this project, and others, and involving also Dr. Perry Cabot. Earlier trials have been conducted around the Great Plains (e.g. Kansas State compilation of 2006 Field Trials), and there has been interest in canola, camelina, rapeseed, sunflower and the Brassicas for a long time, but the subsidy for biodiesel has expired and was not as large as the subsidy for ethanol. This review will note some relevant literature, a speculative effort to support the scenario, and the basic scenario with which the modeling begins. There is also a set of other notes which may save some time for the readers if there is interest in the other literature, or time on sources which may be commercially oriented.

The General Accounting Office (2009) and Oregon Environmental Council (2007) provided fairly comprehensive reviews of environmental issues, but the GAO report was much more informative on corn ethanol, which seems right given the remarkable expansion and high levels of environmental impacts. The Oregon report is more informative on some issues, but there are open questions about the life-cycle costing of farming which attempts to "close the loops".

Baum et al. (2009) is the most comprehensive accounting found, for a multi-enterprise and long-term evaluation; this is a very difficult project. It is also, perhaps, valuable to note that a great deal of the literature on biofuels has been technically competent manipulation of perhaps best-available but optimistic information. The panel discussion and papers published in 2007 by the American Journal of Agricultural Economics seem to exemplify that; a major assumption (not concealed, and likely best available from the literature at the time) was commercialization of cellulosic ethanol by 2012 (De La Torre Ugarte et al. 2007, Eidman 2007, Tyner and Taheripour 2007). The older literature on cellulosic ethanol as an imminent technological rescue seems unfortunately familiar after decades of oil shale being just around the corner. Technological forecasting is difficult, and the politics of subsidies are important in the allocations of research and the funding of university and agency research efforts are also highly variable.

Some information on locally-owned biofuels indicates that economies of scale are pushing for larger and more expensive enterprises, with downward trend in local ownership. There are several business models suggested for small and locally-owned biofuels operations. (Chesnick 2008) but they require elaborate tax credit or governmental program assistance.

Chesnick wrote (2008: 4): “A little more than one-third of ethanol-industry capacity was owned by farmers and other local investors in early 2007, according the Renewable Fuels Association. However, only 15 percent of new or expanding biofuel plant construction is owned by such investors. A key reason for this shift is that the larger plants being built today require larger amounts of equity.”

Chesnick discussed three financial approaches for projects, considering most likely participants to be farmers with gross sales greater than $100,000, net worth greater than $1 million, and debt-coverage ratios greater than $50,000, as most likely to put in from $10K to $50K in to particular projects. The second of three models used debenture guarantees programs similar to Rural Business Investment Companies – they can issue debentures which are pooled and sold to investors, with federal backing and so lower premiums. (A debenture is an unsecured bond, which is to say, an odd thing…). The third model uses “New markets tax credits” from a Treasury program that could designate a tax credit for some investments. A variation on tax credits is designation for projects with a minimum level of rural involvement. The critical goal is local investment in successful projects so that local capital stays in the local economy, rather than increasing shares of investment coming from outside and returns going outside, using the local feedstocks only, and some local employment after construction is over.

As with wind, the public research seems oriented essentially to assist very large capital operations rather than farmers or groups of people. Kenkel and Holcomb (2006) reported at the beginning of the very rapid ethanol expansion that the scale of ethanol and biodiesel projects was rapidly increasing, and so were the expenses of investment. Factors driving location of plants, especially large ones are transport and regulatory requirements for biofuels, and co-product transportation. Wet distillers grains can be fed to cattle but must be dried for poultry and swine. Wet distillers grain can be 30% of weight of feedstock. Oilseed meal from biodiesel can be 60 to 80% of weight of feedstock.

If the biofuel investment is treated as a distinct enterprise, it will be economically evaluated against expectations for the other liquid fuel prices, and expectations for the subsidies and environmental externalities charged or not charged to the particular fuel (e.g. air pollution costs are not presently charged). If the biofuel investment is part of an integrated set of enterprises, there may be some additional accounting, for: (1) the value of the crop in a rotation as an agronomic factor, helpful or not for other crops and as a winter cover crop, and as a crop using water at times when it has low value for other crops ; (2) the value of the stabilized cost of the fuel produced, as fuel per se and as a controlled long-term cost input to the farming and to the buyers of the fuel; and (3) although apparently very unlikely to be relevant, there are issues of food and fuel security, and transportation costs of fuels, and carbon and GHG costs of different fuels. For a given regional integration effort, the stabilized costs may be more important as part of a re-organized reduction of inputs, yields, and net costs and benefits over a multi-year period. There may also be different values involved where the co-product feed is complementary to the livestock operations rather than competitive with them.

There have been more than 15 years of winter canola variety trials, with Kansas State University, and since 2002 other oilseeds including camelina, spring Canola and brown mustard, with support of Blue Sun Biodiesel, and cooperation with San Juan Biodiesel and others (Helm and Johnson 2008). General issues include changing rotations with changes in weed competition, and soil erosion issues – some addressed elsewhere. Climate impacts are not addressed; nor is increased precipitation intensity.

Sunflower, safflower, and soybean have been studied, and Helm and Johnson (2008) summarize findings of research on each crop, and some pros and cons such as availability of crop insurance (yes for sunflower), established markets, and other considerations. Sunflower, for example is a well-studied crop with good experience and knowledge of problems, which works well in no-till and in many rotations, and can be directly harvested with common equipment (meaning, does not have to swathed and dried before being picked up, which increases risk because of the increased length of suitable weather conditions required for success). Sunflower is the second-most popular oilseed for biofuel in Europe. But, it requires extensive water and nutrient inputs, risks poor stand establishment if dry at planting, and provides no significant useful residue. The food oil price was usually greater than the fuel oil price.

Canola is recommended for limited irrigation rotations. Canola can be planted as winter or spring. Fall-planted varieties must be planted before the end of August. The peak water demands for winter varieties are mid-May to Mid-June, before the peak demands for alfalfa, corn and before sunflower, also. Oil content is high, processing is easy, and the meal is a high-protein desirable feed. But the market was not then well-established, not organized as a trade group, and canola has to be swathed before pick-up. It is sensitive to the herbicides used on other crops, and vulnerable to a particular beetle (Helm and Johnson 2008).

Camelina has advantages in being more drought resistant than canola, and can be directly harvested after being grown on dryland or with limited irritation. It also has peak water demand early in the season, after planting early April for harvest mid-July. It is a good match for winter wheat in a rotation using no-till, and can be planted after fall-harvested corn, sunflowers, or millet if there was a wet spring. Winter camelina is tougher than winter canola, and can be planted later in the fall. The meal was not yet (2008) legal for sale as feed (Helm and Johnson 2008). Cross-pollination of Brassicas (includes canola, camelina, rapeseed, mustards) can be an issue that suggests benefits from serious coordination at least on the ditch scale and with neighbors, which might as well include the Arkansas Valley (Oregon Environmental Council 2007).

There was one crushing plant in Lamar, which sent all of its product to Goodland, KS. A plant was planned for start-up in Dove Creek for December 2008. It was established, but not yet for biodiesel. Rodebaugh (2009) reported on Blue Sun. At peak capacity, the plant, which opened December 2008, can process 50 tons per day of seeds, and produce 4000 gallons of oil. Seeds are 35% oil. The 50% dry matter becomes feed meal, and the 15% hull is also pelletized for combustion for heat. Benjamin (2009) found how quickly sunflowers were adopted in a formerly bean-growing area. "We're not going to be the pinto bean capital of the world anymore," said Town Manager Sonny Frazier. "(Sunflowers) are the crop that is going to make the money for the farmer now." Pinto bean production is said to be down by half, as break-even was getting difficult while sunflowers were proving more profitable, and farmers wanted to diversify. Burke (2009) reports that San Juan Bioenergy is crushing to produce vegetable oil, meal and using the waste hulls to make pellets for burning for heat, and exploring additional alternative energy, but not selling biodiesel. The story indicates dry-up of the market for biodiesel as well as the end of federal subsidies.

As a private business, The Big Squeeze biodiesel plant south of Rocky Ford was begun with roughly $100,000 in capitalization for oil seed processing operation that yields 500 to 1,000 gallons/day with some additional improvements and expenses. The intent is to use winter canola as feedstock, and Rocky Ford trials in 2010 produced about 1,000 pounds per acre from irrigations of 2 inches applied in the fall and 4 more inches applied in the spring, at the Rocky Ford Agricultural Experiment Station (Vickers 2010, and Hal Holder presentation to Arkansas Basin Water Forum 2009, La Junta, CO). The owners located this centrifugal plant in a feed lot to avoid almost all of the handling of the residues, with feeding directly to the cattle.

There was also a reported concern with glycerin as a potential pollutant from biodiesel production (GAO 2009). Large operations produce high-quality glycerin and so far have found markets for this substance, which is a feedstock for a large variety of other products. There is concern that a glut of glycerin will reduce the value of this co-product and thus reduce profitability of biodiesel (Oregon Environmental Council 2007). The GAO report adds concern that small refineries are not able to market their output and may discharge it; it is not clear that this would be allowed under normal operations of the Clean Water Act and the NPDES program.

Ideally, planning for a biodiesel operation in the Arkansas Valley would include planning for a glycerin-consuming enterprise as well; perhaps it could incorporate other agricultural products such as fruit or vegetables in consumer skin care products and soaps. The Big Squeeze seems to be a fine demonstration of possibilities and suggests that a regional cooperation might be successful, based on the Bessemer and its cattle feeding and cow-and-calf business linkages.

Rocky Ford trials were included in the 2006 National Winter Canola Variety Trial, with pounds per acre in 2005 trials with excellent stands and fall growth reported, but some weed pressure, ranging from 2500 pounds per acre, down to a few less than a thousand pounds; the high outlier was 3,171 pounds, and the mean was 1,750 pounds per acre with 37.2% total oil. Roundup and Treflan were applied 2 days before planting, but is not stated how many of the trials were GMO canola. Cumulative precipitation in that trial was approximately 7.5 inches; 3 inches of irrigation in fall and 5 inches were applied. Although the information does not measure effective precipitation (which did not immediately run off, as melt on frozen ground surface or rainfall in excess of absorbtive capacity) it is important that these yields were on 15 inches or less. (Kansas State University 2006).

Additional canola enterprise budget information is available but from other locations, and so not easily used, but we report it for background information. Economics information found included Oklahoma 2010 enterprise budget for dryland canola, indicating 19.6 CWT/A production with estimated price of $15.20/CWT would net $112/A, and if using "round-up ready" seed (and round-up biocide), $109/A. The Oklahoma enterprise budget used 19.60/CWT; the Oregon 1995 budget used 11 cents/lb. Futures prices currently reported for Jan 10 – into 2011 are in other units (CDN$/tonne) (see http://futures.tradingcharts.com/marketquotes/RS.html.) The market in Washington and perhaps Oregon appears dominated by Canadian production, but this is not a strong claim! Information for Oregon's Pendleton area for canola in a rotation with winter wheat with 2500 lbs/A yield was found net negative in 1995, and worse than fallow in the wheat rotation instead. (Enterprise budget for Canola (winter) following fallow, Pendleton OR area: Oregon State U Extension Service, EM 8633, October 1995; EM 8632, Wheat (winter) following Canola, Pendleton Area; October 1995). They estimated with 2500 lb/A.) Washington State (Painter et al. 2009) recently reported on Spring Canola for Dryland Eastern Washington, in areas with 12-15 inches of precipitation; at prices received in the recent past, growers would not break even in the less-than-20 inches areas; the prices used were 10 cents/lb and down.

The irrigated Sunflower enterprise budget for Northeast Colorado was based on 24 CWT/A. The sunflower for oil dryland enterprise budget for 2008 was based on 10.79 CWT/A The Northeastern Colorado 2008 Enterprise Budget, Irrigated Oil Sunflowers: 24 CWT/A basis for the budget (with price of $21.70/CWT). (On $3.17 fuel per acre). If one assumes 25% oil content from 2400 lbs, that would be 600 pounds of oil. The dryland NE Colorado budget had 10.79 CWT/A, or about 250 pounds of oil. (http://www.coopext.colostate.edu/abm/nedrysunoil08.pdf; accessed 09Jan10).

There are implications here and there for sustainable farming, such as soy for multiple uses if there is adequate cooperation and capitalization, and ability to muster diversified approaches, such as the use of pork to a greater extent in soy years, and the possibility of moving pork with rotations. The Oregon Environmental Council report suggests, for instance, "roving" facilities for forestry waste handling, to avoid incentives for overharvest from a given area. Ditch-organized areas such as the Valley would not use such a thing, given the low levels of forest wastes, but the idea of movable facilities might work for other small processing in the Valley. It may be more useful to collaboratively develop a commercial community kitchen facility, to be used for projects such as surplus handling, school food processing, charitable food processing and storage preparation, and small seasonal business uses.

The most comprehensive review found was by the Oregon Environmental Council (2007), which reviewed the apparent range of issues, reasons for use of biofuels, and related issues in biofuels technologies. Biofuels can be net positive in energy production, while 1.23 M BTU of natural gas and coal were used to produce 1.00 M BTU of gasoline, and 2.34 M BTU of fossil fuels were used to produce 1.0 M BTU of electricity. Oregon Environmental Council claims biodiesel produces 3.2 units of fuel for every unit consumed through its lifecycle, for 220% net energy gain, while petroleum diesel fuel is a net energy loss of 19.5% according to USDoE and USDA, they say. They also report that NREL found lifecycle CO2 emission reduction of 78% compared to fossil diesel. And, biodiesel exhaust is 60 to 90% lower in toxics.

In terms of world priorities, reduction of greenhouse gases from ethanol seems very unlikely, given its net energy consumption, but biodiesel grown and used regionally may be considerably closer to positive or neutral. A useful point is that the environmental benefits of biofuels are reduced dramatically if CRP or CREP land is used for corn-to-ethanol production. Other determinants such as factory/refinery design can move the process negative or positive. Soybeans were not recommended as an oil seed due to low oil content, though it was not clear if the analysis is of all co-products possible. Soy typically produces 53-57 gal/A of oil, while rapeseed and canola (and other brassica) can exceed 100 gal/A in some cases (Oregon Environmental Council 2007). So, the trials and enterprises for sunflower and canola seem well supported from a light review of the literature.

## *A note on methane:*

Unfortunately, a full effort to capture biofuels and also methane did not appear. Earlier important analyses of fossil fuel to sustainability transitions provided by Lovins, A., 1977, Soft Energy Paths, Penguin, and Commoner, B., The Politics of Energy, Knopf 1979). Biogas from anaerobic digestion uses less capital, heat, and energy inputs than biodiesel or ethanol, but is not fully developed here. It is the fastest growing form of renewable energy in Germany and has theoretically substantial advantages. Direct use of fuels avoiding transformations is always attractive. But, neither the Oregon report not the USDA ARS new story indicate interest in low-capital small on-farm gas processes. What appeared easily in the search involved high-temperature processes that would not seem to be low in cost, though they may be financially positive at large scales.

On small scales, considerably smaller than large feedlots and dairies, there appear to be substantial missed opportunities. Welsh et al. (2010) report that the technology of anaerobic digesters is scale neutral, but the apparent official position of EPA and USDA is that they must be quite big to be desirable. In reality, small operations that will not generate enough gas for electricity generation or running an engine may still provide water heating and cooking, and space heating and refrigeration. Limiting and mis-framing assumptions are that electricity is the required output, and that manure is the only feedstock, so that the technology is defined as very capital-intensive. This is not necessary. These assumptions appear in Key and Sneeringer (2011), from the USDA Economic Research Service. The technological optimization insistence as the only goal, parallel to single-minded pursuit of short-term yield maxima, defeats the “Volkswagen” paradigm of very well-understood, low-capital and easily maintained and customized (large after-market) technology. Welsh et al. also provide a good discussion of the “scientist-centric” view of diffusion of innovations and its implicit view of progress, versus a “farmer-centric” sense of local and shared knowledge. Methane capture from small feedlots would certainly be a local amenity, especially in the summer, as well as a global benefit. Methane is approximately 24 to 25 times more effective as a greenhouse gas than carbon dioxide. Why not gas for heat for grain drying, calving barns, slaughter house and cleaning, refrigeration for meat hanging and other food products, and heat and hot water for food processing? One would expect that local capture and use should be subsidized.

## Canola Scenario

Winter Canola for Bessemer modeling scenarios

Best guess right now, pending better info (with thanks to all for your help) – intended to be on the modest side so as to begin explorations. It is expected that the scenarios tested will also incude use of the figures from the 2005 trials, noted above for Rocky Ford, and the most recent figures from 2010 trials.

For modeling alternatives to illustrate possibilities, and the power of the modeling tool, a set of scenarios using winter canola has been developed. The choices here are made to develop the illustration, and will be modified in use. For example, a very important question is which crop to replace with canola, or whether to use land not in production. For reasons given above, one might choose for a long-term exploration to replace corn with canola. At the time of writing, with very high corn prices (Carrico 2011), this might be the wrong choice, but the virtue of the modeling environment is that one can change these choices very easily, and instead, for example, displace alfalfa. Ideally, users would develop multi-year rotations which might well include a legume for soil nitrogen and moisture reasons, so this is an illustration which would be fleshed out with users in a given location.

SCENARIO: Supposing one replaced corn and expected (given the information about yields of seed and conversion of seed to fuel or food oil) that 15% of total acreage would be “self-fueling”, one might model 20% of acreage to be conservative (in the true senses). Canola water use can be 2/3 of corn crop water use, though there is experimentation under way of deficit irrigation for canola as well as corn. Still being very conservative, and presuming dry weather, 16” of water would be on the high side. Based on interviews with Dr. Perry Cabot, as well as Dr. Michael Bartolo and Dr. Lorenz Sutherland, for the Bessemer one might specify 3 inches at planting and germination time, third week of August; additional 3 inches later September, and then after winter and dormancy, a generous 3 inches in April, also generous 3 inches in May and 3 more inches in June, with an extra inch if needed in a warm autumn. The canola is allowed to dry out when the seeds have matured (see photographs).

Based on the most recent field trials as reported in interviews, local yields can be estimated to range from 50 gallons of fuel per acre with lower quantities of irrigation, up to 100 gallons per acre from full irrigation, and perhaps 80 gallons at about 12-15 inches.

Once a basic scenario is agreed for a given planning effort, the next and very interesting question is how much additional acreage might be devoted to biodiesel production for use by others. In the Bessemer case study, the City of Pueblo owns 27% of the water now. If that were half devoted to producing fuel for the City on a sustainable basis with price stability, as well as fueling the farming of that 27%, there might be substantial economic benefits. The variables one would specify for that include re-setting productivity to consider low-input canola cultivars, rotations with legume such as alfalfa for soil nitrogen, and how much one expects fuels to cost for comparison.

This is also an intriguing example of what we mean by complementary and interdependent changes; almost surely, because of the virtues of good rotations for long-term soil health and input management, large areas should be considered in planning. And that brings the discussion back to organization questions, and the recommendation of operating the ditch as a whole.

## Smart Growth Scenario

As the problem evolved to show the need for a set of complementary and interdependent changes, the need for financing emerged, for a transition which could be initially expensive and might require some time for cost recoupment. The lag in yields in conversion to organics is an example of that, with losses until soil begins recovery and there is diversification of production (Badgley et al. 2007, Gomiero et al. 2008, Baum et al. 2009). An additional pressure for this idea came from the increasing perforation of the farm landscapes, expecially in the Vineland middle section, and the Avondale east section. Controlling such impacts is one of the goals of “smart growth” or “new urbanism” (see references appended to main reference set). On this scenario, we especially thank Dr. Bartolo and Dr. Sutherland for their intimate knowledge of this place, and note that they are not for or against this scenario as an example. We include it as part of the package which might be further considered.

The immediate goal would be to raise capital from sale of interests in the new “village”, available to investors for agricultural support through capitalizing new facilities and management. But an important additional goal is to devise a way to equitably distribute the costs as well as benefits of foregoing development in the farm landscape. The leading discussion of how this can be done in Colorado was presented by David Carlson (2003), and will not be detailed here. He called his organizations “agricultural protective development associations”, and the basic mechanism is transferable development rights used on a private basis.

The capital realized could support a variety of enterprises. At first glance, one might include changes in irrigation technology, support for crop-switching expenses, and direct agricultural investments. Such investments, if for modest incremental changes, might be financed with USDA programs. To take advantage of new capital for the Agricultural Protective Development Association or whatever it is called, with no strings attached, this money might support for “next generation” farmer programs. Going farther into new ideas, this could be used for management of co-op marketing and value-adding processes such as rental and operation of food processing plant, co-op marketing of many farmers’ produce, etc. A “Commercial Community Kitchen” (CCK) seems very desirable. These are institutional kitchens designed for large operations, easy and effective sterilization, and to accommodate changing groups of users. A CCK on the Bessemer might be used by groups other than the growers, which would help finance the operations, including schools and school districts wishing to lower food costs and support local agriculture, and faith-based groups, notably the Church of Jesus Christ of Latter-Day Saints, and other parishes and congregations, and humane organizations. In Boulder, for many years, there were “Gleaning Parties” in which Community Food Share people gleaned from corn, vegetable, and squash fields. (It is a lot more pleasant to do that for a few hours than as labor!).

An additional goal for the new urbanism would be to reserve space and finance a retirement facility for the owners and if they wish, others. A clinic would be very desirable, also, and mixed uses including a day-care/elder-care facility, and space for events as desired.

Financial reorganization might also include a refinance or “reverse mortgages” program for farmers transitioning out and wishing to support new farmers transitioning in…

Not of much importance for the Bessemer, but for many places, note that there are some other interests that would be well served. There are not only private benefits from economies of scale in larger numbers of buyers who get added value from well-designed spaces and amenities, while the farmers stabilize the land use and can plan for the long term. It is also central to the rationale for the transfer of development rights that there are important public interests involved, also. The Colorado practice of “a well by right” for a residence effectively allows more and more wells, closer and closer, and fortunately this has not been universal on the Bessemer, because of the success of the St. Charles Mesa Water operation and local efforts. But there are still water quality impacts from dispersed residences, even if they are using supplied water and hooking up to a sewer system.

The dispersed rural residential development has environmental impacts often disproportionate to the “footprint” occupied, because of cumulation of impacts from roads, impermeable surfaces, and any unregulated septic systems (including interactions with domestic water wells). The dispersed development also has disproportionate effects on wildlife. First, there are increased “edge effects” from the perforation of habitats, roading, increased traffic and noise and changed timing of human activity, changes to wildlife corridors and habitat connectivity, and resulting changes in the kinds of wildlife and their interactions. Second, the rural residential development is often located in the more interesting parts of the landscape, for obvious reasons of the charms of being near riparian areas, variety, and habitat, so the impacts are higher than if the development was intended to reduce impacts or located randomly. (The best single source on these impacts may be Ecological Applications vol 15 issue 6 special issue on rural residential development.)

The dispersed development is also more resource-intensive; many of the residences within the Bessemer are not practically within walking distance of anything but the neighbors, so automobile use is constant and the costs of that can only be expected to increase. Children and the elderly have effectively very little mobility.

Another issue is the conflict between enjoyment of the rural and farming landscape versus the disamenities of equipment on the roads, odors, and noise and dust from field operations. There are some “right to farm” ideas gaining popularity, but the goal of this Village idea is to get the best of both worlds, with capturing value from the landscape used for farming, and providing high-efficiency pleasant housing.

Finally, it is also very important that value of property is based on security of expectations: the sense of the future. A house in a place with no land use controls is subject to the risk that the neighbors who appear may have very different interests; it is therefore almost universal in towns and cities to prevent some unwanted impositions. These typically include limiting the location of dangerous activities, such as those involving risky chemicals, and limiting the location of businesses and their hours. Houses in "nice" neighborhoods are worth more than those with no security of expectations. The Village should provide, because of the stabilized landscape, security of the amenities of open space, being near farms rather than other land uses, compatibility of development with customer preferences (desirable amenities and quality of life features) and compatibility with local preferences (e.g. amenities for retirees etc. and perhaps additional facilities of value such as medical clinic, day-care for children and seniors, etc.)

The scenario modeling when fully developed will include: (1) diversion of some additional irrigation water from Bessemer into Saint Charles Mesa Water District, for simplicity; (2) effluent from development and if added to Vineland or Avondale clusters, including effluent from the existing clusters as well as the new through a modern sewage treatment plant; and possibly (3) use or application of effluent to wetlands mitigation banking/recharge/augmentation plans with some revenue from that, and/or application to augmentation needs for well users who would presumably pay for such use, with some revenue. The treated wastewater might be exchanged for additional flows, particularly in off-irrigation season timing, which could be used for support of wetland and riparian support programs.

One very important decision for scenario thinking is whether or not to avoid the loss of farmland or sacrifice some. Location near existing clusters has advantages for the existing businesses, but disadvantages in changing the character of the existing clusters, and disadvantage of losing some very good farming. With that in mind, a 230 acre set of parcels adjacent to Avondale was chosen for modeling, with an additional parcel for a horse-boarding and recreation facility. This reduces the extension of utilities, and while it changes Avondale, should add desirable services and facilities for Avondale and the East and Central parts of the Bessemer. This would add traffic to and from US 50 and on Business 50, but avoid adding much (one hopes, but without benefit of engineering analysis) on the small quiet roads in the farming area. It is also possible that a Village addition to Avondale (or Vineland) might help renovate aging infrastructure in the town, by means of agreement or establishment of a financing mechanism such as a special district.

Locations where there is no farming now, such as the "Badger Hills" to the South of the Ditch idea, may preserve character of existing clusters but also increase traffic seriously in currently rural areas, shifting some impacts, and may involve much higher infrastructure costs, and may be less desirable quality of life as isolated; and Dr. Sutherland also immediately noted that new development "out there" may be in competition with existing businesses, which might expand with new customers. That area is appealing to some people, judging by a few houses and trailers along the roads south of the Bessemer, but it is of a quite different character than the areas near farming, the early higher density Blende area, and the residential clusters along old highway (now business) 50, Vineland, and Avondale, and Arkansas River and the riparian areas.

Infrastructure costs for higher density development are dramatically reduced compared to low density. Typically, this is a cost that is financed by long-term debt such as bonding and improvement districts. New developments may include infrastructure costs in sales prices more effectively than incremental expansions onto older areas. New developments may also be organized to avoid the problem of sudden spikes in the average costs used for utility pricing, which may adversely affect prior residents (see Local Government Commission 2003: 7).

This scenario is for illustration, as an approach to show the idea. Real development would involve professional planning and many skills not available for this project.

Density can be defined several ways, but most useful for modeling is gross density, the total residential units/total development area. The most likely alternative to "smart growth" in most of rural Colorado is one residence per 35 acres, which is the area exempt from county land use regulations. On the Bessemer, there are smaller parcels carved out and converted from farmland, partly made feasible by the water district. Density is very important: the EPA (2004) notes that if Manhattan's population were at suburban densities, it would occupy about the area of Rhode Island. Good examples of new urban development (illustrated and on-line) include:

- Aggie Village, Davis CA, 30 units/A on 4.5 A residential, with 3.5 A retail, 15000 square feet open space; Local Government Commission 2003: 5, 16-17, 33.

- Wellington Neighborhood, Breckenridge, CO: 5 and more units/A; Local Government Commission 2003: 12.

- New Holly Urban Village, Seattle, 9.5 units/A on 110 A site with 1358 mixed-income housing units, and community center with library, childcare, open spaces and community gardens interspersed, greenbelt, retail center, residential, institutional space planned. Local Government Commission 2003: 20-21, 31.

- Kentlands, Montgomery Country, Maryland: 236 acres made into 2,100 residential units and 2 Million square feet of retail and commercial space. Net density of 9 residential units per acre. (EPA 2004). This is not an appropriate scale for Bessemer thinking, and there will be some delays before there is public transportation to and from Pueblo, and at this point no guarantee of transportation extensions or their usefulness. But it is one of many examples to show what careful use of space can provide.

For scenario development, a first question might be the number of residential units, which sets some water needs, especially for indoor uses. This is a pick-your-number question, because it is so design-dependent. It seems best to assume that each residential unit will have some outdoor space, for a yard and garden, but not a large space. This is a design consideration and it is very likely that a mix of residences would be created, with some "townhouse" style and some apartment style, with different amounts of yard/garden and set-back from interior streets.

SCENARIO**:** On 230 A in two parcels (see illustrations), near Avondale on the east end of the Bessemer, we suggest model 100 A in residential at 10 units/A average, for 1000 residences on total site, at build-out. This presumes townhouses, condo apartments, and assisted-living suitable, with open space interspersed.

The second task is to estimate outdoor water needs. It seems likely that most units will have some outdoor space; not 1/4 acre lots, obviously, but some garden and outdoor private space.

And, the Village as a development would have decently efficient outdoor watering for the parks, medians, etc. A design question: how much space will be outdoor and not paved or hard-scaped? Good modern design would divert hardscape runoff into softscape areas, which might not be official rain gardens, as used in the East, but would take advantage of flows and reduce overall runoff. Rain gardens are not a clearly “good idea” because of Colorado water law, but use of permeable areas is certainly not prohibited.

SCENARIO: For a start, on the 230 A parcels, we can model 100 A open space, and roadways, parking, with watering needs for 70 A. With somewhat intensive gardening and community gardens on some of this, one breakdown might be 20 A getting flower-and-vegetable-and-ornamental 30 inches /year, 30 A getting xeriscape establishment, at perhaps 10 inches/year. 20 A might get turf watering at 20 inches/year.

The third question: what are the water needs for nonresidential development? Here, design considerations are certainly wide open, and we did not investigate LEED standards or other specifications. Colorado is considering standards in the context of conservation recommendations and expectations in the Statewide Water Supply Initiative (SWSI) studies

<http://cwcb.state.co.us/water-management/water-supply-planning/Pages/SWSI2010.aspx> (Full report approx 40 MB, not counting tech appendices; conservation studies continue.)

SWSI 2010 Section 4: fig 4-2 and p 4-8: Colorado state average 172 gal/cap/day. Does not provide commercial use or outdoor use breakdowns. SWSI 2020 App. H : State of Colorado 2050 Municipal and Industrial Water Use Projections: also uses gallons/capita/day but these are not recommendations, and are based on current kinds of uses.

SCENARIO: For modeling now, the fall-back is the projections, but conservation could be included as desired, to bring down the commercial/industrial uses figures.

The fourth question here concerns the water needs for the associated development. To provide the most-sought amenity and recreational value for “country” living, we suggest a condominium horse stable which would be within walking distance from the new village.

SCENARIO: This can presume that the majority is turf or paddock, and that there is horse watering and cleaning and restroom facility uses in barns, need for water for cleaning barns. Here, further inquiry is needed, but for modeling we can simply modify some information from water uses in a feedlot or other animal operation.

An appendix to the reference set is provided with source material on this topic.

## A note on amenity and recreational values from agriculture

Agriculture provides both intangible amenity and aesthetic values, important to quality of life for many people, and more tangible benefits. These include both increased real estate value from proximity to amenities and recreational opportunity, for local people, and tourism and visitor recreation as well. The enormous value of in-coming tourism is widely appreciated though estimates usually do not include amenity value for residents of the place. Also, estimates usually do not count the benefits from people retiring in a place because of amenities, or building second homes. This is a huge contributor to rural growth (McGranahan 1999), and should be considered essential for future economic development in Colorado's non-metro area. The modification of the environment of Colorado is ubiquitous, and in some cases very destructive of present interests and preferences (see Baron, J., Ed., Rocky Mountain Futures, 2002, Island Press). The value of environmental qualities is sometimes assumed to be roughly correspondent to the altitude, with ski areas wanting to look as if they harbor a pristine environment, and lower-altitude farming and ranching areas are assumed to be contemptuous of non-commercial species. That view does no justice at all to the stewards of the majority of the land, and ignores the critical value of the environmental amenities which are driving rural growth and will play an increasing role in the future. (This generalization comes from occasional reviews of some of the literature on targeting conservation efforts, a large literature with a large number of emphases; Sassenrath et al. 2010). (A USDA "briefing room": http://www.ers.usda.gov/topics/view.asp?T=104024 and an article: http://www.ers.usda.gov/Amberwaves/Feb03/features/ruralamerica.htm.

Hunting, fishing, and non-consumptive wildlife uses (birders spend a lot) are especially important benefits of riparian and wetland resources in rural Colorado, especially in areas away from skiing and where there has been little or no public investment in recreational or amenity development; typically, what there is consists only of motorboat facilities. In 2007, hunting and fishing in Colorado provided more than $1.0 Billion in expenditures on trip expenses and equipment. With secondary economic impact this was "just over $1.8 billion." In 2006, wildlife watching expenditure and secondary economic impacts are estimated to be $1.2 billion (BBC Research and Consulting 2008). The State appreciates this: "In many areas the local economy is dependent on these amenities [from non-consumptive water uses]. Much of the reason we have job and population growth is because of Colorado's recreational and environmental opportunities. Businesses move or stay here because of this. In order to move forward on water projects, environmental needs will have to be met." (Colorado Water Conservation Board, (2011, Proceedings of the Statewide Roundtable Summit, 03 March 2011, available on website of Colorado Water Conservation Board. P 2, Executive Summary).

NOTE: This is not the complete report; there are also two sets of illustrations (a file of photos and a file of powerpoint slides), and another large part from David Yates, in preparation.

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Williams, C.L. 2009. Rural development and Iowa's future agriculture.

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Prepared for the Summit for Visioning Iowa's Future Agriculture. Formerly available at:

http://www.agron.iastate.edu/agsummit/WORKSHOPS/climateglobe.pdf.

http://www.agron.iastate.edu/agsummit/WORKSHOPS/energy.pdf.

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## ***Smart Growth and New Residential Scenario***

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There are older reports, also, now probably too out of date (1970s, 80s).

## A Note on National Research Council (2010): Toward Sustainable Agricultural Systems in the 21st Century

And a later addition: the National Research Council has just published a report of two workshops, which are quite interesting on these problems, but please note that this not a typical thoroughly vetted and reviewed National Research Council publication. The presenters' work has been summarized, and one of the interesting qualities of this is the lack of agreement on some points (in Wiener's opinion). National Research Council, 2012, A Sustainability Challenge: Food Security for All: Report of Two Workshops. Washington, D.C.: National Academies Press. (Available at no charge as download; slides sets also posted.)

Brief Notes on National Research Council, 2010, **Towards Sustainable Agricultural Systems in the 21st Century** (downloadable at no charge, summary or any or all parts) <http://dels.nas.edu/Report/Toward-Sustainable-Agricultural-Systems/12832>.

Explanation: The 2010 report is 600 pp, and as one would expect, thoroughly supported with extensive citations, and very carefully written. It was deliberately not read before writing the November 2011 report on the Bessemer Arkansas project contexts, to review the authors' understandings of the situation during the series of projects. This note is to provide reference to the National Research Council document on a few points that are clearly relevant, to make that document more quickly accessible for our friends. The opinions here are the author's. A few claims of fact are noted where of particular relevance but readers are urged to treat this as a highly selective sampling; fortunately, later editions of Adobe Reader ™ have search functions to assist along with the table of contents of the report.

**Preface and Chap 1**: introduces their definitions of systems agriculture, and robustness, defined as a mix of resistance of system to being dislodged from some stability, resilience as ability to return to state from which dislodged, and adaptability as opposite of vulnerability (spread; see 25-26).

26: Sustainability sought by moving systems toward sustainability; they do not recommend a fixed target or goal, but processes of moving towards meeting all four of the sustainability criteria, which include meeting demands for [4 F] food, feed, fiber, and fuel; environmental quality; economic viability; and quality of life for farm families, farm workers, community and society. They use these 4 to characterize tradeoffs.

There is considerable discussion in spots of the long-term adaptive capacity versus short-term management goals, and how these relate, but the majority of such discussion appears to be in the specifics of particular agricultural practices, in Chap. 3, examples of farms using different farming systems, Chap. 7, and at the beginning in Chap. 1 and end in Chap. 9.

**General comment:** Perhaps the most important contribution beyond the specifics is in the discussion of "transformative" versus incremental change, and in the recommendations of landscape and watershed scales of analysis and holistic examination. Diversification and improved organization of mixes of farming systems at these scales is argued in the beginning and end as very desirable, and it is noted that there is little research on this. They mention work on nitrate reduction from improved placement of farms and non-farm vegetation and wetlands, and recommend more research and development of tools to enable such landscape design (see especially the short conclusions chapter, 9).

29: The question of who decided on priorities is raised, but there seems little direct recognition of underlying questions about property rights distributions and consequences. They discuss the need for careful consideration of incentives, particularly in policy driven programs such as the commodity and conservation payments programs. But, the presumption of private property rights to externalize costs is not questioned, even where there is passing note of the marginal erosion of the general agricultural exemption from pollution controls (see Chap. 6 on drivers and constraints).

**Chapter 2**: Includes brief history of U.S. agriculture, with greater information about market concentration and specialization than I have seen in USDA publications (see pp 45-48). They also cite Heffernan and Hendrickson 2007 and other works, but not much from USDA on this point. There is about no discussion of the role of infrastructure, such as railroads, water ways and highways. But, they do get to the very rapid concentration and vertical integration of the agri-food business; more comes up later in the report. Specialization: average 5.6 commodities (for sale, one expects) were produced on the average farm; in 2002, the average was 1.3.

There is a good discussion of what the Bessemer Arkansas report calls "bifurcation". In 2002, 75% of total farm sales from the top 6.7% of Farms. They discuss the categories of farms. See also Pp 69-71.

Pp 49-51: "**Small and mid-sized family farms together owned two-thirds of the total value of farmland, buildings, and equipment and managed roughly 60 percent of all U.S. farmland and cropland in 2007**. Therefore, they will continue to play an important role in efforts to improve the environmental footprint of agriculture, and their experiences and activities will continue to shape the social and economic well-being of farm families and agricultural communities. Interestingly, the proportion of small and mid-size operations that have chosen to participate in federal land conservation programs is larger than that of large operations. Eighty-four percent of all land in federal land conservation programs managed by small and mid-sized farms. Small and mid-sized farms received 88 percent of U.S. total government payments for conservation programs in 2006 (Hoppe et al., 2008).

"In addition, 70 percent of organically certified land in the United States was managed by small and mid-sized farms in 2007 (although they accounted for only 30 percent of total organic product sales). In contrast to the small and mid-sized farms, million-dollar farms–that is, those with annual sales of at least $1 million–accounted for nearly half of U.S. farm product sales in 2002, even though there were only about 35,000 of them. They represent only 2 percent of all U.S. farms (Hoppe et al., 2008). Most million-dollar farms were operated as family businesses, and many reflect joint operations that support multiple family members and households. These types of farms particularly dominate the value of U.S. production of high-valued specialty crops (72 percent), dairy products (59 percent), hogs (58 percent), poultry (55 percent), and beef (52 percent). In some crops, production is concentrated." (Pp 49-51.) (**Emphasis added.**)

Nearly half of farm sales were by the top 2% of farms. In categories, operating margins from farming operations look to "break even" and go positive at about $175 K in sales (p 51).

Farms with more than $250 K /year in sales hold 79.7% of the irrigated lands (p 50).

Ethanol was use of 23% of 2007 corn crop; biodiesel was use for 17% of soy crop (p 54 and see 54-57 on biofuels).

Biodiesel from non-soy sources seems overlooked. Canola is mentioned on a list of crops for which transgenic research has been conducted, and in a case study of one of the farms described.

Rate of prime farmland conversion was averaging 400,000 A/yr 1982-1992, but increased radically to more than 600,000 A/yr in 1992-2001 (p 57). Loss of land for high-value specialty crops is noted. Esseks et al. 2007 study not mentioned, but discussion of urbanizing areas.

Water availability and climate are treated in this chapter and a few other places where relevant, such as discussions of water resource management in more detail in chap 3. It is Wiener's opinion that they understate threats of climate variability and increased intensity of precipitation along with changed seasonality and “clean fallow” (see pp 59-61).

Soil quality problems are introduced, and adverse effects from “some” modern agricultural practices.

Water quality and the fate of contaminants, biocides, hormones and antibiotics are discussed more thoroughly than I expected, but new information on development of resistance may be missing.

Losses of genetic diversity are well discussed here and elsewhere (pp 66-67).

Farm net versus gross economics are discussed, with observation that net has been generally flat for 40 years, with gross sales increases countered by increased costs of production (p 67). For the 87% of farms with sales <$250k/y, there was only 7% of the net farm income; about 80% of net income want to bigger sales farms (p. 69).

Good treatment of little overlap of farms receiving commodity payments versus farms receiving commodity payments. (p 69).

Farm structure and community well-being are discussed P. 73.

This overview chapter ends with remarks on the need for landscape scale approaches. Does not cite Managing Agricultural Lands for Environmental Quality I or II (Cox and Schnepf, Eds., 2007, Nowak and Schnepf 2010).

**Chapter 3** discusses practices, impacts, prevalence, pros and cons, with depth for some with research to report. Includes treatment of conservation tillage, cover crops, etc. Concludes (p. 161) with point that soil quality is “basic and critical” for sustainability. References pp 164-188.

**Chapter 4** is on economic and social dimensions of sustainability.

Discussion on p. 190 of complexity of policy, economic, market and social contexts makes the value of Elinor Ostrom framework clear (this report cites a researcher on ag systems and small ag at Washington named Ostrom, by coincidence, also).

Civic agriculture, connections between farmers and federal agencies, and other issues of community are treated in this chapter, and there is discussion of the amenity values of agriculture as a source of community quality of life. Seemed short on real estate values and economics of rural residential development (see pp 206-207).

There is solid discussion but not much to cite for them on the point that:

“Conducting research on the social and economic performance of farming practices and systems is complicated by the fact that their economic “viability” is always influenced by the specific development and constellation of market and policy conditions. Similarly, social impacts or social “acceptability” of individual farms can be influenced as much by the behavior of key actors and the values of community members as by inherent qualities of specific production practices or farming systems. These complexities do not make research on social or economic sustainability impossible, but require a more extensive base of research findings and more complex research designs to draw strong conclusions. Given those limitations, review of the scientific literature by this committee suggests several important conclusions:

- “The economic benefits of some farming practices accumulate over time as the farming system becomes more resilient. Long-term economic assessment of farming approaches would provide valuable information on economic sustainability of different practices.” (Pp 211-212.)

The references section for this chapter includes materials not seen for Bessemer etc. report (pp 212-219).

Chapter 5 is on example of farming system types. Discussion of the comparisons that are lacking so far includes the point that long-term complex rotations must be considered as best basis for comparison of possible choices (pp 228, 235 ff).

The report is good on the difficulties of comparisons, but seems rather shy on the important point about net from multifunctional efforts being affected during times of transition where badly-degraded soils with reduced soil organic matter, moisture-holding, and reduced microbial life must be restored and will yield at lower levels until recuperated (Badgely et al. 2007, other citations, doubtless). There is gap in long-term and holistic comparisons (pp 253-254).

There is another good discussion (pp 255-258) of the landscape and watershed scale, and relevance of nested levels of interaction (they used “tiered”, p. 258).

Chapter 6 is on Drivers and Constraints affecting transitions toward sustainability, with review of programs and again, treatment of market concentration, again relying primarily but not exclusively on Heffernan and Hendrickson.

The top 4 seed companies supplied 2/3 of corn, 1/2 of soy, and almost 90% of cotton; there are similar levels of concentration in key inputs, and issues of profit are raised. Similarly, the top 4 firms control more than 80% of grain exports, 2/3 of soy, 84% of beef, 66% of pork, 59% of poultry… (pp 271-274).

The extent of market concentration in wholesale food, food and beverage sales, and retail food sales in similarly disturbing (pp 274-275).

There is a discussion of changing consumer preferences, but not about the change from “organic” to “local” which Wiener argues is quite important in Bessemer Arkansas Valley report (based on Adams and Salois 2010 and other references cited in report and subsetted in references for report).

Adoption of farming systems is discussed pp 329-331 in this chapter, and the role of different levels and scales of influences is discussed.

**Chapter 7** is on illustrative case studies of farms using different farming systems in different places, and extensive details run from pp 353 through 492.

**Chapter 8** is on applications of the study findings to Sub-Saharan Africa.

**Chapter 9** is the conclusions and recommendations chapter.

Here, the idea of transformative change reappears, with some additional detail and recommendations.

*"TOWARD AGRICULTURAL SUSTAINABILITY IN THE 21ST CENTURY*

Although all farms have the potential (and responsibility) to contribute to different aspects of sustainability, the scale, organization, enterprise diversity, and forms of market integration associated with different individual farms provide unique opportunities or barriers to improving their ability to contribute to global or local food production, ecosystem integrity, economic viability, and social well-being. Transformation of the agriculture sector will require long-term research, education, outreach, and experimentation by the public and private sectors in partnership with farmers and will not occur overnight.

"If U.S. agriculture is to address the challenges outlined in Chapters 1 and 2, both incremental and transformative changes will be necessary. Therefore, **the committee proposes two parallel and overlapping efforts to ensure continuous improvement in the sustainability performance of U.S. agriculture: incremental and transformative. The incremental approach is an expansion and enhancement of many ongoing efforts that would be directed toward improving the sustainability performance of all farms, irrespective of size or farming systems type, through development and implementation of specific sustainability-focused practices, many of which are the focus of ongoing research a with varying levels of adoption. The transformative approach aims for major improvement in sustainability performance by approaching 21st century agriculture from a system perspective that considers a multiplicity of interacting factors.** The transformative approach would involve:

• Developing collaborative efforts between disciplinary experts and civil society to construct a collective and integrated vision for a future of U.S. agriculture that balances and enhances the four sustainability goals.

• Encouraging and accelerating the development of new markets and legal frameworks that embody and pursue the collective vision of the sustainable future of U.S. agriculture.

• Pursuing research and extension that integrate multiple disciplines relevant to all four goals of agricultural sustainability.

• Identifying and researching the potential of new forms of production systems that represent a dramatic departure from (rather than incremental improvement of) the dominant systems of present-day American agriculture.

• Identifying and researching system characteristics that increase resilience and adaptability in the face of changing conditions.

• Adjusting the mix of farming system types and the practices used in them at the landscape level to address major regional problems such as water overdraft and environmental contamination.

Continuing with excerpts:

"*INCREMENTAL APPROACH TO IMPROVING U.S. AGRICULTURAL SUSTAINABILITY*

**The proposed expanded incremental approach would include focused disciplinary research on production, environmental, economic, and social topics, and policies (such as expanded agricultural conservation and environmental programs) to improve the sustainability performance of mainstream agriculture.** For example, large livestock farms in

the United States produce the majority of the nation's meat and dairy products. Similarly, a large portion of corn and soybean are produced on highly mechanized grain farms that specialize in the production of a small number of crops and rely heavily on purchased farm inputs to provide crop nutrients and to manage pest, disease, and weed problems. Most, if not all, farms have adopted some practices for improving sustainability, and some farms, including large farms illustrated in the report's case studies, are highly integrated, but such methods have not been adapted to all environments, and none of the practices have reached their full potential for adoption. Each of these production systems has fostered high productivity and low costs, but many have led to serious negative social and environmental outcomes (or externalized production costs) that could hinder agriculture's progress toward improved sustainability. The negative outcomes have led to policy changes and publicly funded research programs explicitly designed to address those concerns. Efforts to improve the sustainability outcomes associated with mainstream production systems might be incremental in nature, but could have significant benefits given the dominance of those production systems in U.S. agriculture." (Pp 521-523; emphasis in original).

And, another:

"**The transformative approach to improving agricultural sustainability would dramatically increase integrative research by bringing together multiple disciplines to address key dimensions of sustainability simultaneously beyond the agroecological dimension. It would apply a systems approach to agriculture that could result in production systems and agricultural landscapes that are a significant departure from the dominant systems of present-day agriculture.** This approach would facilitate development of production approaches that capitalize on synergies, efficiencies, and resilience characteristics associated with complex natural systems and their linked social, economic, and biophysical systems. It will emphasize integrating information about productivity, environmental, economic, and social aspects of farming systems to understand their interactions and address issues of resilience and vulnerability to changing climatic and economic conditions. Moreover, integration would include expanded attention to the role and development of new markets, new policies, and new approaches to research and development that are likely to sustain a systems-oriented agriculture." (Pp 525-526; emphasis in original.)

Another excerpt:

**"Although a landscape approach to agricultural research could inform the design of agroecosystems to maximize synergies, enhance resilience, and inform what policies would be useful in influencing collective actions, programs to encourage such research do not exist.** [Emphasis added.] Examples of transformative landscape-scale research include:

· Develop systems-type mixes, patterns, and technologies for landscape diversity that maintain economic output while reducing overall water use.

· Develop systems-type mixes and technologies to reduce nitrogen, phosphorus, and pesticide losses to downstream fragile water bodies, particularly in source regions responsible for hypoxia.

· Develop tools for modeling of systems and patterns for multipurpose economic, aesthetic, and environmental impacts to enhance community well-being and assist in planning, local policy making, market identification, and farmer decision making.

· Develop policies and legal frameworks that encourage cooperative watershed landscape and ground water management across field and farm boundaries.

· Generate landscape design options to increase resilience and adaptability to changing conditions using a combination of the above approaches." (Pp 529-530.)

They recommend research support for watershed and landscape scale studies, and long-term studies, and research which includes more farmer participation.

**A General Comment:** The problem of private individuals making decisions in increasingly abnormal environments, both physical, and social, is in Wiener's opinion seriously overlooked. It is simply insufficient to call for more research studies and call for increased funding for extension. The needs are greater than even restoration of funding cuts could meet. The need is for genuinely enabling people to undertake adequately informed adaptation and inquiry into transformative change beyond the capacity of scientific and extension group intervention.