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Potential for Market Systems/Carbon Trading

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Executive Summary

If carbon sequestration concerns are to be addressed through markets, the cap and trade mechanism is perhaps the most likely approach that will be taken in solving the carbon problem. This is based in part on experience with the sulfur allowances market that is being implemented starting with the 1990 Clean Air Act Amendments. It is recognized, however, that a great deal of uncertainty surrounds the matter of whether we might see emission allowance markets and the related carbon storage markets anytime soon. As a result, the bulk of the report is devoted to highlighting the major parameters that will have to be considered, especially in designing markets for carbon offsets in stock (COIS) certificates.

Emission limits would need to be set before emission allowance markets could be formed. Carbon storage markets would likely appear next. It may well also be the case that farmers and ranchers would be faced with covering emissions of carbon and other greenhouse gases, while also being able to sell carbon offsets in stock for the carbon stored in land. Also, the report highlights problems with green payments or markets in flows and in promises to apply best management practices. Neither of these two approaches seemingly make a close enough connection to the scarcity 1) in the atmospheric capacity to hold more carbon dioxide, or 2) in the agricultural soil and land capacity to store more carbon. Emissions allowances and carbon offsets in stock make these connections, and, as a result, are more likely to produce jointly equitable and efficient outcomes in both payment programs and markets.

The report also takes the reader through an exercise in understanding how flows of carbon into a tract of land relate to the stocks of carbon in storage. A hypothetical set of numbers relating stocks and flows are presented in two figures, one showing the kind of time path one might expect for the level of carbon stored and the other showing the accretions, or the rates and flows of change in the carbon stock for each unit of time. The flows are affected by how much carbon is already in the soil at any point in time. It is demonstrated that as we approach the capacity of the soil to hold more carbon it becomes increasingly difficult to add more carbon to storage. This leads to the contention that the additional costs of increasing the flows into the soil will only be incurred by farmers and ranchers if payments and prices also increase over time, and as we reach full storage capacity.

The report then turns to addressing the nature of a property right in carbon stored, the carbon offsets in stock (COIS) certificate. Various dimensions of COIS property rights are explored including the right to possess/exclusive control; right to use; right to manage; right to the income; right to the capital; right to the security; right to transfer; right of term/duration; right to prohibit harmful use; right to execution; and, right to residuary character. It is clarified that a COIS is somewhat unusual in that even though it is sold, the seller is still in charge of managing the carbon in place such that the

relationship between the buyer and seller has to be maintained during the time of contract. Also, it is suggested that perhaps the seller be given the option of buying COIS certificates associated with other land and providing same to the buyer if for some reason it is necessary to reduce the carbon stored in stock on the land in question. Rather than providing penalties for carbon stores being reduced, it is suggested to provide flexibility to the seller on how the contract can be satisfied.

In terms of progress toward carbon storage markets, it is pointed out that after the Title IV Amendments to the 1990 Clean Air Act resulted in actions to set national emission limits and to create a sulfur allowance market, it took about 3-years to introduce a market. Some 7-years after introduction, the market is now functioning quite effectively. Perhaps a 10-year horizon on setting emission limits leading to emission allowance and perhaps carbon storage markets is realistic for carbon as well. It is also highlighted, however, that recent moves in the U.S. Congress to introduce somewhat opposing pieces of legislation in terms of eventual outcomes bears watching. If the Conservation Security Act of 2001 passes, green payments may substitute for market prices in carbon stores, flows and/or for best management practices. If the Clean Power Act of 2001 passes, emission limits will be set on carbon emissions, which could then lead to carbon emission allowance markets. There seems to be a potential for disconnect here, using standard subsidy/payment programs in one case and the new cap and trade market mechanism in the other, placing the two approaches somewhat at odds.

The report emphasizes the need to focus on carbon offsets in stock, i.e., focus on carbon stored in land rather than on flows into the land or on best management practices, no matter whether we face green payments or market prices. Nebraskans may wish to develop a simulation exercise to help in experimenting with such a market on a case study, or special project basis. A Nebraska Coalition, modeled after the Montana Coalition, might be formed to work with farmers and ranchers in putting together aggregates of carbon stored for possible sale. It also is noted that perhaps the Nebraska Natural Resource Districts and the Nebraska Department of Natural Resources could play a role in certification and as a central point for data on transactions and features of the trade in offset certificates. Nebraska based private sector firms also could be encouraged to consider providing certification and aggregation as well as brokerage and financial services in the new carbon markets.

Fortunately, Nebraskans are a step ahead of most in other parts of the U.S. with respect to proactive involvement on carbon issues. The State could continue taking the lead on this front, with the plan to further influence the conversation about the nature of the payment or market mechanisms that eventually evolve in carbon. Designing and testing a simulated and perhaps even a test market in carbon offsets in stock in a selected project area might be considered.

Potential for Market Systems / Carbon Trading[1]

Gary D. Lynne and Colby E. Kruse[2]

If we are to keep the market from overrunning everything else we hold dear, we need competent states. And if we don't want the state to be its own source of tyranny, we need strong democracy (Kuttner, 1999).

The task of this paper is to explore the various design features of a carbon offsets or carbon storage market that might evolve in Nebraska and the Great Plains region more generally. Such a market could arise due to voluntary "baseline and credits" approaches leading to trading in offsets, or due to limits on emissions set by governments involving private sector trading in "cap and trade" approaches. Both approaches create a demand for places to sequester, that is, to store carbon in place, such as in the upper root zone area of agricultural land. In either case, as we approach the limits on the capacity of the atmosphere to hold more carbon dioxide, we will likely experience rising prices in both the emissions and the carbon storage markets, and/or see growing government green payments focused on sequestering more carbon. The fascinating political economic question rests on whether individuals will become sufficiently concerned with setting limits and building markets themselves, or if the concern will have to come through government setting limits on emissions. Also, the question of the mix of government controls, subsidies and market mechanisms is yet to be resolved. As the quote from

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Kuttner (1999) suggests, an appropriate mix reflects a kind of delicate, we may even say symbiotic, balancing as between market and government involvement, both operated on democratic principles.

No matter where the limits arise and mix of mechanisms we ultimately choose, the current political dialogue seems to suggest that the market will play a substantive role in the matter in any case, at least if the current administration is able to set the tone and direction of the conversation. President George W. Bush, while deeming the carbon emissions limits in the Kyoto protocol unrealistic has simultaneously indicated "I've asked my advisers to consider approaches to reduce greenhouse gas emissions, including those that tap the power of markets, help realize the promise of technology and ensure the widest possible global participation (NY Times, June 12, 2001)." It is noteworthy that the sulfur emissions market was implemented during the previous Bush Administration, and Governor Jeb Bush of Florida, the President's brother, has favored the use of markets help water allocation in Florida. Given the recent pronouncement by President Bush that we will "tap the power of markets" it may not be unrealistic to expect that we will see some kind of carbon market(s) within the next few years.

We cannot necessarily predict the kind of markets or market mechanisms that might emerge here, or if certain elements of the U.S. Congress will instead manage to pass some version of the Conservation Security Act which will give green payments for sequestering carbon (see Lynne and Kruse, 2001). We can only speculate with some reasonable level of confidence about the main considerations in designing carbon markets. In order to highlight the issues in forming such markets, we draw especially on frameworks and ideas provided in Bromley (1989; 1991); Colby (2000); Ellerman et al. (2000); Fiske (1992); Kuttner (1999); Lynne (1999); and Lynne and Saarinen (1993).

Nature of the Carbon Right to Be Traded, and the Carbon Markets That May Emerge

We can see the possibility that farmers and ranchers would someday be engaged in trading in Emission Allowances (EAs). Each operation would establish a carbon emissions baseline, and be given EAs, perhaps measured in a 1-ton allowance for each ton of carbon currently emitted. Then, EAs no longer used due to changing technology and practices to farm with lower emissions of carbon, e.g., using less (hydrocarbon) fuel, could then be sold to another firm (perhaps another farm) that has to cover emissions and finds it less expensive to buy an allowance than to make the technological switch. Emission Allowances could be related to Best Management Practices (BMPs), i.e., claiming a lower level of EAs needed for each BMP as compared to conventional practices. Each BMP would be associated with a certain EA requirement, and by definition a lower emission allowance than the allowance needed to cover conventional technology and practices. So, adopting a BMP would free EAs established in the baseline for sale on the market. The problem with this approach is that it creates incentives to document a high baseline (i.e., initially show emissions of large amounts of carbon and other green house gases) such that more allowances are given at the outset.

In addition, farmers and ranchers may soon find opportunities for trading in Carbon Offsets (COs). A farmer or rancher might be paid for a net, positive flow of carbon into the land, C_{net}, where $C_{net} = (C_{in}-C_{out})$, the amount in less the amount out, and

$C_{net} > 0$. One may also be paid for the carbon stock, C_{stock}, the amount retained *in situ* (in place), stored in the land, from year-to-year. We might refer to the former, the C_{net}, as a Carbon Offset In Flow, i.e., a net inflow of carbon into the land, or COIF, and the latter, the $C_{stock,}$ as a Carbon Offset In Stock, i.e., carbon in place in the agricultural land, or COIS. It is not clear at this time as to whether markets might arise in the net annual in-flows; in the stocks in place; or, in both.

The problem is that paying farmers and ranchers for net inflows into the stock without paying for stock in storage will, behaviorally speaking, create a perverse incentive to deplete soil carbon content so that one could again be paid for flows into the stock within the land. If the market only pays for the net inflows in any given year and not for the established carbon in the soil, profit-maximizing landowners and managers will likely mine (plow-up) the soil to make room for "new carbon (Zeuli, 2000, p. 239)."

To avoid these perverse incentives, the carbon market will have to be constructed carefully. For example, a two-tier pricing structure, one for already stored carbon and one for annually sequestered (new net inflow) carbon, could be utilized. Market forces could determine the equilibrium price differential between the two. Perhaps better yet, only a market for carbon stored in place and trade in a COIS certificate, perhaps each certificate measured in 1-ton units, would be developed.

Paying only for stock in place and trading only COIS certificates would create an incentive to increase the rate of net inflow as well as to maintain the stock, so we see only a positive incentive from the stock side. In fact, it may be desirable to focus all the attention on the stock in place and thus leave the concern about the flow into and out of the soil to the farm or ranch manager. This also obviates the need to regulate technologies and to mandate best management practices, thus giving more freedom of choice and less government intervention. With everyone focusing on carbon stored, we do not have to be concerned with what and how technologies and practices are used to sequester carbon in the land, or how it is released, except in the scientific and educational sense needed to help farmers and ranchers manage the carbon flows.

The desirability of focusing on the stock in place, and thus on payments or prices for COIS, is reinforced by recognizing that the rates of sequestration and release and the maximum potential capacity of a soil to hold carbon vary greatly. Each soil in a particular situation and time sequesters and releases a variety of different kinds of carbon at different rates, which in turn is affected by how much carbon is in storage relative to the capacity at some point in time. Also, each soil also has a different maximum storage capacity. We might expect the relationship like that depicted in Figure 1 (hypothetical) depicting one situation, representing total carbon stock stored in an acre of land over time.

The shape of this function follows that of Lal et al. (1999, p. 85), who draw a similarly shaped curve showing total carbon stored in all cropland in the U.S. as plotted against the number of years to reach the capacity of the land. It is suggested that it could take another 50 years, until about the year 2050, to reach the top capacity for U.S. cropland to hold carbon.

Stock and Flow Relationships

The soil on this hypothetical acre in Figure 1 is eventually full to capacity at about 70 tons of stock in year 100. Once the soil is fully stocked, we could expect a long flat, plateau area of the curve, suggesting the 70 ton stock would be maintained at capacity perhaps indefinitely. We can now also illustrate how the rate at which carbon is sequestered, i.e., accretions or the flow (Figure 2) each year, will be related to how close we are to capacity in the stock (Figure 1) at any point in time. Relating this back to the carbon offsets market idea, the COIF market would operate with the flow illustrated in Figure 2 while the COIS market would operate with the stock illustrated in Figure 1.

To see the relationship between the stock and the flow, assume we are now in year 42, with 48 years to go until the soil is full to capacity at year 100. At year 42, we have about 35 tons in stock, i.e, stored in the land (See Figure 1). The pace of increase, the flow, at this time will be fairly fast, as shown by the flow curve in Figure 1 being quite steep at year 42. In fact, this is the fastest accretion or flow rate possible as illustrated in Figure 2. When the stock is 35 tons (which happens to be "now" in year 42, the accretion or flow rate is 1.75 tons per year, and we are at the top of the flow curve (Figure 2). As the soil fills, however, the growth rate slows (moving down and to the right of the peak in Figure 2, and toward the plateau of Figure 1), making it ever more difficult to increase the carbon in storage. The flow declines. For example, when we have 60 tons sequestered, the flow is in the vicinity of 0.80 tons, and at 65 tons the flow is only about 0.5 tons (Figure2).

Importantly, this decline in the flow or accretion rate as we move to the right in Figure 2 and the movement to the plateau in Figure 1 also means that it will be ever more costly for farmers and ranchers to increase the amount of carbon stored in the soil as the capacity is reached. It will be substantively more costly to add 0.5 tons to the soil when the stock is approaching 65-70 tons than it was when the stock was less than 10 tons (a point at which the accretion rate was also 0.5 tons). We would also expect, then, that the price of COIS certificates would have to increase over time in order to provide a sufficient financial incentive for farmers and ranchers to keep adding carbon. As we move toward the peak of the flow curve in Figure 2 we would expect costs to declining; as we move further to the right beyond the peak, we would expect the cost to be increasing rather rapidly. While we do not know the exact breakover, we might expect this kind of pattern as we move from conventional tillage through 30% residue cover in conservation tillage until we reach 100% residue cover in no-till.

The numbers in Figures 1 and 2 are hypothetical and for illustrative purposes. What kind of actual accretions and capacities might we expect to experience in Nebraska conditions? The scientific research is in short supply on this front. It has been suggested, however, that for commonly used rotations and soils here in Nebraska where the carbon stock has been substantively reduced since the prairie was plowed, that accretion could run as high as 1-2 metric tons/ha-yr in rainfed systems (Lal et al., 1999), and 2-4 metric tons/ha-yr in irrigated systems (Duvick and Cassman, in press). This gives a range of 0.45 tons per year on rainfed to 1.75 tons per year on irrigated. Research in Nebraska has also shown that a typical corn field currently has about 90 metric tons per hectare (about 40 tons per acre) in storage in contrast to grassland on the same soil type holding about 150 metric tons per hectare (about 67-70 tons per acre).

Carbon, potentially, also leaves the soil. The residence time of carbon in the soil varies greatly from a few minutes to hundreds of years and is dependent on the size of soil particles with which the carbon is associated (Buyanovsky et al., 1994, p. 1167). In the pool of soil organic matter (and there are several different kinds), vegetative particles not yet decomposed have the shortest residence time. The rates of degradation appear to be inversely proportional to size, with residence time of 1-year for large plant fragments to 2-years for very small particles. Organic matter in macro-aggregate form shows residence times of approximately 10-years. Carbon associated with the silt and clay portions of the soil are reported to be in residence approximately 400- years and 100-years, respectively (Buyanovsky et al., 1994, p. 1172).

To better understand the release idea, and again using the two figures to illustrate, assume now we are currently at a stock level of 70 tons per acre. If the farming practices on this tract shift to mining the carbon out of the soil, we will move back to the left on the growth curve in Figure 2, and down the curve to the left in Figure 1, i.e., stock in the soil will be declining. As a result, the growth rate increases (the rate is higher to the left of the 70 tone point in Figure 2) and the farmer could again sequester carbon at a more rapid rate, and at lower cost. If payments were being made for COIF (i.e., for accretions) rather than for COIS (i.e., for storage), moving to the left by mining carbon out of the soil positions the farmer or rancher to again enjoy rapid rates of increase in the amount stored each year while being paid to re-sequester the carbon again.

The rate of carbon release is also influenced by the vegetative cover. A study performed by Jenkinson (1977, p. 429) illustrated that soil that had been under grass cover for 5-years contained 47% more of the originally added carbon than the same soil that was kept bare for 5-years. The same experiment also showed some disturbing results. In this experiment, one soil was kept under grass for 5- years, then plowed under and left bare for the remaining 5-years. A second soil was kept bare for the entire 10-years. At the end of the 10-year period, the soil that had grown grass for 5-years and then kept bare for 5-years contained just slightly more carbon than the soil that was kept bare for the entire 10-years (Jenkinson, 1977, p. 429). Grazing was shown to decrease soil carbon levels in an experiment performed by Parton et al. (1987, p. 1173). This is to say, how we manage the land once it is in some crop moves us left or right in Figure 2, and affects the flow rates. It also affects the amount in stored in stock as illustrated in movements left and right in Figure 1.

All this seems to suggest that if soil is to be used as an effective place to store carbon arising in carbon dioxide emissions, some land might have to be off-limits to any disturbances whatsoever, with other land mildly disturbed (e.g., grazed), while still other land would be farmed without concern for how much carbon is stored. Alternatively, we would have to seek the optimal amount of carbon to store in each soil/crop combination looking at the marginal (additional) benefits and marginal (additional) costs across the mixes with the goal of equating the marginal net returns from carbon stored in each. Which approach will be best has yet to be determined.

Such biological and physical complexity adds to the complexity in the relationship between the Emission Allowance (EA) and the Carbon Offset in Stock (COIS). One might reduce the use of carbon on a farm such as through using less fuel in conservation tillage which creates extra EAs that the farmer could sell, and an increase in COIS available for sale. Alternatively, using less tractor fuel might result in using more herbicides which also are produced with hydrocarbons, so perhaps the farmer even needs to purchase extra EAs (i.e., perhaps emitting even more carbon than with conventional practices), even though COIS has increased. That is, one can conceive of a situation where using large amounts of carbon inputs could increase soil carbon in storage while emitting more carbon than with other input packages. Also, if markets in COIFs evolve, and depending upon relative prices in the COIF and the COIS markets, the farmer may find it advantageous to buy back the COISs in order to mine out the carbon, and then sell accretion (net inflow) on the COIF market. In any case, we would expect at least two different markets emerging, one in EAs and one in COISs, and, conceivably, even a market in COIFs albeit this one creates problems unless there are also markets in COISs. If markets or green payments for best management practices also emerged, the complexity is compounded even further.

Also, farms and ranches emit other kinds of greenhouse gases, so we perhaps cannot focus all the attention on carbon. In addition to carbon dioxide (CO_2), the greenhouse gases include the hydrofluorocarbons (HFC) and perfluorocarbons (PFC); sulfur hexafluoride (SF_6); methane (CH_4); and nitrous oxide (N_2O). Agriculture is also part of the problem as well as the solution for all of these gases, especially the methane and the nitrous oxide as well as carbon. Domestic livestock (and manure) production generates large amounts of methane; denitrification and nitrification process are enhanced by adding synthetic and organic fertilizers, resulting in releases of more nitrous oxide; and substantive quantities of hydrocarbon fuel are used to power agriculture, as well as to build the machinery and to manufacture the pesticides and herbicides, and thus agriculture also contributes substantive amounts of carbon dioxide to the atmosphere. Agricultural crops also naturally produce carbon dioxide as well as use it in growth. Fortunately, crops use more than is released, especially under certain kinds of agricultural practices, e.g., minimum tillage, which is what leads to the potential for agriculture to be part of the solution to the carbon problem.

We need to remain cognizant of the other gases produced in agriculture, however, and the possibility that emission limits might also be placed on these gases. If such limits were place on methane and nitrous oxide gases, e.g., farmers and ranchers might be faced with finding offsets for these emissions, perhaps having to buy emissions allowances for methane and nitrous oxide. It is not outside the realm of possibility that farmers and ranchers could be faced with buying (and selling) emission allowances, EAs, in methane, nitrous oxide and carbon allowances markets while simultaneously selling carbon offset in stock, COIS, certificates in a carbon storage market. It remains an open question as to whether farms and ranches would see a net profit from this buying and selling activity.

There is also another subtle similarity between EAs and COISs that perhaps needs to be understood, and also adds strength to our contention that COISs need to be considered over COIFs or BMPs. We already know that the EA approach works for the emission problem; by analogy, because they are similar in concept and definition, it seems reasonable to argue that a COIS will also work for the storage problem. There is good reason for this success.

In particular, when an EA represented in a 1-ton emissions allowance is placed on the market for sale this means that someone has found a way to reduce emissions by 1-ton. Similarly, if a 1-ton COIS certificate is offered for sale, this means that someone has found a way to store a ton of carbon. In both cases, we are making progress toward, at minimum, stabilizing the total amount of emissions at the overall limit (or, perhaps even reducing the total if someone who does not need to cover emissions still buys a 1-

ton allowance), or, we are keeping still another ton out of the atmosphere by storing it in the land. In contrast, with a sale of a COIF certificate or a promise to install a Best Management Practice, we have accomplished neither: All we are paying for is effort that may or may not stabilize (or reduce) emissions. We could be anywhere left or right on the growth curve of Figure 2, and in some undefined location on the stock curve in Figure 1. Neither the COIF or the BMP are attached directly to the real limits we face, which is the capacity of the atmosphere to absorb more carbon dioxide and the capacity of the land to store more carbon. By focusing on EAs and COISs, respectively, we connect with the scarcities that will define these markets or payment programs.

Just the potential complexity alone among market types reinforces the suggestion that the focus is perhaps best placed on the stock of carbon in place, and on forming the COIS market. And, as alluded to in foregoing, we would propose that a carbon offset in stock, COIS, be represented by a 1-ton certificate, the certificate ensuring that this 1-ton is indeed in place (certified) in the soil. A certification agency or a private firm providing this service for fee would be asked to do the checking and the re-certifying on a periodic basis.

Legal Instrument Actually Used

Is carbon in storage represented in a Carbon Offset in Stock certificate a mineral right? Or, would the certificate be traded simply through a business contract for service? In law, carbon in the form of coal in place in land is a mineral and thus falls under mineral law. Organic matter in place in the soil is also carbon, so is it a mineral falling under mineral law, or rather treated like other kinds of manufactured inputs added to soil like commercial fertilizer? If the latter, the matter of trading in COISs falls to business and contract law. This general consideration needs to be resolved in legal research, and perhaps made a matter of law.

Focusing on the COISs, specific considerations in defining the nature of the legal instrument used in trading are now considered. The main categories for consideration are drawn from Bromley (1989, pp. 187-190). We offer a suggested way to design the new property right in a carbon storage commodity, although it is fully understood that the details all remain to be resolved:

Right to possess/exclusive control. Once the number of COIS 1-ton units is certified on a farm or ranch, and the 1-ton certificates have been sold to a buyer, the buyer will have express control over it, although the seller still has certain duties associated with it. Generally a seller will have to maintain the stock in place for the buyer, with the buyer having recourse if the stock is somehow depleted during the contract period. Perhaps periodic re-certification that the 1-ton is actually in place would be required. Alternatively, the right may be defined from the outset as having various probabilities that the stock of carbon in place will vary, perhaps with weather conditions, and thus allowing for some flexibility in the amount of carbon that needs to be maintained in place by the seller over the duration of the contract. Perhaps the certificate would carry a range, e.g., guaranteeing only that 1-ton plus or minus 0.10 ton will actually be in place at any given point in time. Also, perhaps the total tons for a larger area could be guaranteed, with variation among particular tracts within a larger area recognized as normal.

Right to use. The buyer would have the right and responsibility to claim the Carbon Offset in Stock is doing the work of holding carbon dioxide out of the atmosphere.

Right to manage. Intriguingly, the right to manage the Carbon Offset in Stock would probably not be sold to the buyer. The initial seller (farmer or rancher) would retain this right.

Right to the income. Generally, it might be expected that the buyer of the COIS certificate would have the right to any income that could be produced by perhaps leasing the COIS to someone else during the contract period.

Right to the capital. The right to the capital associated with a COIS would be retained by the seller. The land holding the carbon has the capital value. A valuable COIS certificate would add capital value to the land. Seemingly, we could also separate the COIS for sale separately from the land, much like a mineral right. The COIS may best be sold with the land, however, in that the owner would likely be ultimately responsible for how much carbon is stored.

Right to the security. The matter of security of the right is complex in that carbon may escape from a particular part of the landscape due to natural forces. Perhaps the market will eventually distinguish the lower from the higher risk carbon stock in the market. Prices for a stock of carbon in a rainforest, e.g., may be higher than for the stock of carbon in a corn field simply due the lower volatility in the forest. Another aspect of security is simply that the buyer has the right to that particular amount of carbon stored during the contract period.

Right to transfer. Presumably a buyer could sell the Carbon Offset in Stock to another buyer, with only the need to inform the original seller. In light of the carbon staying in a particular place no matter who the buyer, the new buyer has in effect become connected to the original seller once a buyer has sold (or leased) the COIS to another buyer.

Right of term/duration. Seemingly we will need annual durations, i.e., that in any given year a buyer will have to hold a certain number of Carbon Offset In Stock certificates with that years date on same. A farmer or rancher would likely re-sell COISs each year, much like selling any other commodity. Alternatively, it may be possible to sell the COISs projected to be available each year at the outset of some contract period (Zeuli, 2000, p. 244), e.g., 10-years, especially for those who have perhaps almost reached the capacity of the soil at the top of the curve in Figure 1, and thus have substantive amounts of carbon stored. In this case, too, each COIS certificate would have a time subscript attached to it, making it usable as an offset in that particular year only. The discounted, annualized value of this one time payment at the beginning of the 10 year period would have to be compared with the current annual payment that could be obtained this year, and a decision made as to whether to commit to a 10 year plan or simply re-sell the COIS certificates every year. Some may prefer the lump sum payment at the beginning; others may wish to take the perhaps greater risk of market fluctuations year to year and enjoy the higher average payoff over time. Under a 10 year plan, perhaps penalties for intentional carbon release would have to be built into this system (McCarl, 1998 in Zeuli, 2000, p.. 244), although this is a moral issue with many not seeking only the self-interest. That is, penalties may not be necessary, especially if the

the farmer or rancher is allowed to cover any losses in storage by purchasing COIS certificates from someone else. Purchased COIS certificates would be made available to the buyer holding the COIS on the land in question. This would give the seller of a 10 year supply flexibility, which leads to efficiency. It could also be a moral efficiency, in that the sellers and buyers can avoid immoral behavior (i.e., mining out carbon stocks that have been sold) by covering any mining with purchases in an efficient COIS market. This is an important consideration in designing a market and points to the intricate connection between the moral dimension and the economic efficiency dimension of markets.

Also, we may need to expect that the duration of the contract will be heavily influenced by the natural and physical aspects of carbon. As suggested in Figure 2, ssoils can sequester carbon for years, but once they are plowed, that sequestered carbon can easily be lost. The whole purpose of a sequestration project is then compromised as much of the carbon is turned to the atmosphere as carbon dioxide.

Right to prohibit harmful use. It is difficult to see how a Carbon Offset in Stock could lead to any kind of harmful use. Yet, as with all ownership in the U.S., this is a standard feature of owned property, i.e., one does not generally have the right to harm others with ones property.

Right to execution. A buyer would perhaps best be given the right to sell the Carbon Offset in Stock certificate to another buyer at any time during the contract period, e.g., selling the COIS certificates associated with year #5 to another buyer. The original seller (land owner) would have the right to sell the COIS to another buyer at the end of the contract period, no matter what buyers held the COIS certificates at the end of the period.

Right to residuary character. If a buyer for some reason abrogated the rights, presumably any remaining storage value would revert to the state, until such time as the contract ended, and the seller could re-sell the Carbon Offset in Stock to another buyer.

Measuring, Monitoring and Enforcement

A critical aspect of establishing a carbon emissions trading market in COIS is the measuring, monitoring and enforcement of soil carbon levels. The measurement and monitoring difficulty is compounded with the current situation of there being no universal method used when testing for soil organic matter. Also, soil testing is relatively expensive. A basic soil test that measures organic matter and soil nutrients usually takes samples over a 5-20 acre area and costs around $25/sample (NRDC, 2000, p. 6). These costs may be high when compared to the potential value of soil carbon. There are several possibilities, however, for lowering the costs of measuring soil carbon. Enforcement is also impossible without good measurement and monitoring tools and capabilities.

One possibility for approaching measurement is by combining sampling of other soil characteristics (e.g., fertility) with carbon sampling. Many farmers already take annual soil samples for the purpose of testing for fertility. Perhaps the organic matter testing could also be done at this time. For this to work, timing requirements of soil carbon measurements must be met (NRDC, 2000), and will be conditioned by the risk levels acceptable to those participants in the market. Another possibility is for the U.S.

Natural Resource Conservation Service to expand the Natural Resources Inventory to include carbon flux, although this is a sampling procedure with the focus on larger areas of certain kinds of soils. This inventory is conducted every 5-years, and the next inventory coincides with the Kyoto Protocol's first commitment period (NRDC, 2000), although now even the Protocol itself is in question. Including soil carbon in these inventories, however, could involve considerable additional planning and implementation costs. Also, connecting these data to actual aggregations of tracts of land could be problematic unless the same boundaries were used for the testing and the aggregate sold on the markets.

Assuming low opportunity costs on time during off-seasons, measuring and monitoring costs could be greatly reduced if farmers collected their own samples instead of hiring professionals. Once a sampling site is identified, soil sampling can be done with only modest equipment and skills (NRDC, 2000). Also, permanent plots could be staked out which could be found later and retested in each period. Although lab costs vary on a state-by-state basis, analysis of farmer collected samples including a test for organic matter content costs between $2.50 and $9.00 per sample for a farmer collected sample, although this price reflects a public subsidy (NRDC, 2000). Such a subsidy might be justified, however, as part of the (social) transactions costs associated with the carbon market(s); perhaps some public investment in soil sampling could be justified in light of the public benefits that would likely be gained from having more carbon sequestered.

Remote sensing could also possibly be used to measure soil carbon changes. Experts contend, however, that remote sensing would need to take place more frequently than satellite information is presently generated (NRDC , 2000). In addition, if the focus is on best management practices rather than soil carbon, we see another problem: As noted by the NRDC (2000), parameters based on estimates of the frequency of different farming practices may be difficult to prove or disprove at a single farm level.

Also, we need to keep in mind that some degree of measurement error in soil carbon stocks may not be a barrier to establishing an efficient carbon storage market, although insurance and contract mechanisms could be developed to account for error. Zeuli (2000, p. 239) makes a similar observation regarding payments and markets for best management practices: "For example, farmers within a fairly homogeneous region could receive an average carbon sequestration rate per acre with the adoption of no-till. As long as market regulators accepted this average, with the knowledge that it represented a range of expected carbon sequestration rates, no further precise measurement would be needed. Markets can accept some uncertainty and still function efficiently." We would expect that a COIS certificates market would also be able to handle some imprecision in the measurement of soil carbon as well.

One possibility to supplement actual field level measurement is suggested by the use of simulation models, such as the Century Ecosystem Soil Organic Matter Computer Model (see Parton et al., 1987; Metherall et al., 1993; and Paustian et al., in preparation, all cited in Natural Resource Conservation Service, 2001). This model uses information and data on current cropping and tillage systems in place on the land and the resource data on characteristics of the climate and soils to simulate rates of carbon sequestration (NRCS, 2001, p. 4). Another tillage system can then be introduced or expanded, e.g., more no-till farming, and new estimates of higher rates of carbon sequestered developed.

To the extent such a model is accurate within tolerable limits, it perhaps could serve to make claims to potential buyers of carbon storage that the carbon is actually in the ground. These kinds of models could perhaps be used to supplement actual ground measurements, determining how much carbon is actually in place. Measurements over time could also be used to calibrate the model. The advantage of such simulators is in their cost of use, with the possibility of developing literally hundreds or thousands of simulations under a variety of conditions for quite modest cost.

Assuming we can solve the storage content measuring problem, including perhaps ways to simulate such content, we still need to address the monitoring and enforcement problem, although the latter disappears under good design. It is likely though that participation in monitoring would have to be mandatory (NRDC, 2000), much as it is a precondition for participating in the sulfur market (Ellerman et al., 2000, p. 9). As noted earlier, enforcement becomes largely a non-issue other than the need to have the soil carbon content re-certified on a periodic basis, if the seller is given the flexibility of substituting COIS certificates purchased elsewhere for carbon stored in the land at that place.

Initial Determination of Tradable Emission Allowances and Carbon Offsets

As suggested from the experience with establishing the baseline allocations of emission allowances in the case of sulfur (see Ellerman, 2000 as summarized in Lynne and Kruse, 2001), establishing baseline allowances for methane, nitrous oxide and carbon on farms and ranches could be even more difficult, due if for no other reason than to the large numbers of operations. It remains to be seen whether emissions allowance markets could even be established at that level of specificity. Even though difficult, however, it is not outside the realm of possibility that an agency like the U.S. Natural Resource Conservation Service could play a substantive role in determining the baseline on each farm. The NRCS already has helped large numbers of farmers and ranchers develop conservation plans. It seems establishing a baseline of emissions for each kind of greenhouse gas emitted on each farm and ranch could be done within the context of a conservation plan.

In terms of carbon offsets in flow and in stock, it seems that measuring the flow could be far more costly, however, than measuring the stock. Other than for research purposes, such measurement is perhaps out of the question at an operational level, on a day-to-day, year-to-year basis even with the best of precision agriculture approaches. Measuring the carbon in place in the stock of the soil, however, seems workable as suggested in the previous section. Again, it seems the focus needs to be placed on the carbon offsets in stock idea, and seek ways to certify both the stock of carbon in place at the outset and on a continuing basis. Again, perhaps the conservation planning that is being done jointly between farmers/ranchers and the NRCS could also lead to a way to include the carbon stock in the soil as part of the datum showing the status of the plan as well as serve to clarify the goal of the plan, i.e., to reach some point toward the plateau of the carbon storage curve in Figure 1. Sound economic analysis would also need to become a part of the conservation planning process, however, in that it will not likely be appropriate from a strictly economic efficiency perspective to operate with the soil filled to capacity, although a jointly moral and efficient purpose could lead to such a point.

Continuing Certification of Carbon in Stock (and Perhaps the Net In Flow of Carbon)

Once a market is operant, both new and previous buyers in the market for Carbon Offsets in Stock will need to be assured how much carbon is still stored, or, if the government payment or market price is for net inflow of carbon, how much is indeed moving into the land in any given interval of time agreed to in the contract. A certification entity could be a government agency, e.g., the U. S. Natural Resource Conservation Service, or, perhaps a state entity like the Nebraska Natural Resource Districts, or the Department of Natural Resources. Perhaps all three could play a role, such as planning and baseline determination in the NRCS; certification in the NRDs; and maintaining a central data base on carbon trades in the DNR. It is also possible that private firms could provide the baseline and certification service for a fee. It is probably best that data bases be maintained in the public realm, however. For example, the SGS, an international firm, recently certified the amount of carbon in stock within several Costa Rican rainforests (See Lynne and Kruse, 2001). The amount of carbon traded on international markets, however, would probably be best registered in an agency of the United Nations as well as by local agencies like the Nebraska DNR, and national agencies like the U.S. EPA.

Frequency of certification also needs to be determined, although one period may not have to be universally applied to all situations. For example, it may not be necessary to re-certify the amount of carbon in a grassland as frequent as would be needed for an annual crop like corn. Perhaps a re-certification could be done every 3-years for annual crops and every 5-years for grassland. Also, perhaps remote sensing could somehow be applied every year with soil sampling done on even longer intervals to check and calibrate carbon storage prediction models, with the offshoot that prediction models associated with remote sensing could be improved over time.

The spatial dimension must also be resolved. Perhaps measuring, monitoring and certification could all be done on a watershed basis, e.g., with tracts of land at that scale brought to market with carbon storage certified to be at least a certain level across the entire watershed. Working at a watershed level could also give more bargaining power with large companies who are buying carbon offsets in storage. The problem with working at the watershed scale in area wide sampling is the disconnect with specific farms and ranches; knowing where the sequestration and storage maintenance is actually taking place; and ensuring ensure those who are actually applying the effort are rewarded for their actions. Some mechanism would have to be developed to ensure any payments or market revenues received from the aggregate sale are distributed in a just and fair manner back to those farmers and ranchers making a difference in the watershed. We see the potential role for an aggregator: Perhaps the aggregator would do the area-wide testing only in the areas associated with the farms and ranches the aggregator has managed to bring together into a more or less contiguous block of land.

Or, Initial and Continuing Re-Certification of Best Management Practices and Technologies on the Farm/Ranch?

Some seem to believe that carbon sequestration can be accomplished by establishing payments or market sales of guarantees by a farmer to apply certain Best Management Practices (BMPs). This seems to be the flavor of the recently introduced Conservation Security Act (see Lynne and Kruse, 2001). This is also the approach of the Canadian consortium of power companies in working through the Iowa IGF crop insurance company (see Lynne and Kruse, 2001). Options are being negotiated on the possibility of farmers promising at some point in the future to apply certain packages of best management practices. Payments and market transactions are focused on the certified BMPs on the farm.

Much as with the payments or markets in carbon flows into land, potentially serious problems exist for this strategy, in that one cannot easily verify that practices are being applied, now how well the practices are being applied. Inappropriate application of a practice could result in little to no carbon being sequestered. Also, it is not always clear just what a particular BMP, or how it is applied, does to the rate and level of carbon sequestered in the soil. Also, the effectiveness of a BMP will vary greatly dependent upon where the farm is situated in Figure 1 and Figure 2.

Some also believe that it may be feasible to provide predictions of the effects of various best management practices by a field level carbon sequestration model that is sensitive to local soil types, crop rotations, climate, tillage, cover crops, and organic amendments. The USDA Agricultural Research Service is currently developing this type of model, named CQESTR, that will compute decomposition rate and residence time in the soil of carbon from organic matter, roots, crop residue, and organic carbon. (See: http://warp.nal.usda.gov/ttic/tektran/data/000011/22/0000112230.html). This model will use data sets that are available nationally. Such models could perhaps be used as one tool for associating applied BMPs on a particular farm or in a region with the expected levels of carbon that may be sequestered, but perhaps can never substitute for actual field measurement of carbon changes or, perhaps better yet, measurements of carbon actually stored in place.

Need for Aggregators

No matter the nature of the commodity traded (i.e., Carbon Offsets for net inflows or storage in place, or promises to apply best management practices), it will likely be the case that at least some buyers will prefer to purchase larger aggregates, e.g., perhaps 70 million tons of carbon stored on 1 million acres rather than 70 thousand tons on 1000 acres, and more than likely wanting to deal in aggregates of more than 70 tons on one acre.[3] For large operations, perhaps the individual manager could enter the market with the carbon stored in place on that unit. For small and even mid-side operators, however, it may be necessary for some kind of aggregator organization to bring together small amounts of sequestered carbon into larger packages for sale. It seems reasonable to expect that most buyers may wish to deal with one aggregator rather than hundreds or perhaps thousands of smaller offerings.

The recent involvement of an Iowa insurance company in approaching approach individual farmers is again a case in point. The insurance company played this

[3] Then again maybe not: The current sulfur allowance emissions market sells as little as 1-ton at a time to individual buyers. Eventually there could be literally millions of sellers, offering small numbers of 1-ton allowances for sale on both the sulfur and the carbon allowances market. This could also evolve for the

aggregating role in negotiating the deal with the consortium of Canadian power plants (see Lynne and Kruse, 2001). Also, the Montana Coalition serves this role by approaching individual land owners and in helping them with tree plantings, with the carbon stored by aggregates of land owners then made available on the market through a private corporation (Montana Watershed, Inc.) associated with the Coalition. Intriguingly, this aggregating function could be done by the private sector (e.g., the Iowa insurance company) or the public sector (e.g., the Montana Coalition that operates at least in part on public funds, but is connected privately through the Montana Watershed, Inc. unit).

As noted, in Nebraska one possibility would be to ask the Nebraska Natural Resource Districts to take on this role. The Districts are organized more or less on watershed boundaries, which now would also become carbon boundaries in the sense of aggregates of carbon stored within a particular watershed. Buyers could potentially approach purchasing any magnitude of carbon stored that they desired from a few tons to the potentially hundreds of million tons stored in some of the larger watersheds. The Districts in turn would work with individual landowners, and serve to certify that the carbon is actually stored on the land in question.

Private aggregator companies may also emerge in Nebraska. If a public entity like the Natural Resource Districts was not pressed into such service, more than likely such private companies will indeed emerge. Also, the Nebraska Unicameral may wish to consider the model represented in the Montana Coalition that was originally formed with a legislative appropriation to hire an executive director and staff to serve in helping the

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carbon storage market. Web and internet technology is such that it would not be impossible for each land owner to offer Stored Offsets In Stock perhaps even from small acreages on the peripheries of urban areas.

aggregating function. A Nebraska Coalition could in turn work with the NRDs in a productive way, perhaps the NRDs serving mainly in the role of certifying that the carbon is actually stored in place while the Nebraska Coalition could serve the aggregating function.

Trading Entities

Related to the matter of aggregators, the question of who would be allowed to trade in carbon offset markets needs to be resolved. In the case of the sulfur markets, electric power utilities are both the main sellers and buyers of sulfur allowances. Yet, the market is not closed, with even individuals allowed to participate in buying and selling allowances. An individual can purchase a 1-ton sulfur allowance and give it as a birthday present to an environmentalist friend, for example!

We might also realistically expect that brokerage firms, real estate agencies and other kinds of environmental financial products firms may enter the fray. As highlighted in Lynne and Kruse (2001), the Environmental Financial Products, L.L.C., company of Chicago recently helped negotiate a trade between the Montana Coalition who represented two native American Indian tribes and an United Kingdom firm. We might also expect carbon bankers, like the International Carbon Bank and Exchange (see Lynne and Kruse, 2001), to provide clearing house services.

Trading Overview and Approval Process

Much like with sulfur emissions trading, we would anticipate that any carbon emissions and carbon offsets trading will be ongoing across state and national borders as if the borders did not really exist, nor will it matter the source of the carbon. It will also not matter where the carbon is sequestered, just so long as it is sequestered, and stays in place. This reality raises fundamental questions, though, about who will keep records on who is sequestering how much carbon when, where and how much is stored. At the national level, perhaps we would ask the U.S. Environmental Protection Agency, or the U.S. Department of Energy, or perhaps the U. S. Natural Resource Conservation Service to provide this service. As noted in Lynne and Kruse (2001), EPA now provides a central point for keeping all the records on how many sulfur allowances are available and being held where and by whom. Perhaps the climate change division of the United Nations could provide this service on a world-wide scale. The important point is that something equivalent to the EPA national data base, or, if we need to become even more formal in the law, perhaps something equivalent to the register of deeds now used in the U.S. to register land trades needs to be established for carbon Carbon Offsets in Stock certificates. In fact, we may even wish to use the current structure of county registers of deeds in Nebraska for this purpose.

We would also anticipate that much like for regular land transactions there would not be any need for government overview or pronouncements on the nature of the conditions of the trade. Individuals could buy and sell COIS certificates without approval of some outside entity. The only requirement of the buyers and sellers would be that such trades be registered and made a matter of record in some central location. It would also be desirable that the agreed to price be recorded at that same location. One would then also anticipate that prices could be made public information, which would then improve the quality of trades on later rounds of trading.

Fees to Cover Administrative Costs

It is not likely that Nebraska's Natural Resource District could play any substantive role in carbon storage trading or in certifying stocks in place without additional funding. It seems, though, that each transaction could be charged a small fee, not unlike a real estate agents fee, at the time of the transaction with such funds made available to the NRDs. Alternatively, if the private sector takes on this function, perhaps something on the order of 5% of the value of the transaction would become a realistic fee, with the percentage perhaps lower for larger transactions. Also, depending on how this evolves, we could see fees for certification being separate from fees for aggregation and brokerage, with separate entities involved in each.

Linking Use Levels to Resource Conditions

Some central entity will have to keep score to see that overall limits on emissions are being met; that the same number of emissions allowances are always in place covering the emissions of each firm; and, that the carbon is indeed remaining sequestered as represented in the number of Carbon Offset In Stock certificates currently issued. As noted earlier, perhaps the Nebraska Department of Natural Resources could play some role here, as well as the U.S. EPA at the national level, and seemingly some division of the United Nations at the global scale. Aggregators could play a key role in providing high quality data to central points.

Likely Success of a Nebraska Carbon Offsets Market or Payments Program

In order for a carbon offsets market or a green payments program for storing carbon to be effective, the value of stored carbon must be high enough that farmers and other landowners would adopt technologies and practices that would sequester more carbon. Currently, many landowners are mining carbon from the ground by tilling the land and otherwise farming they way they currently do, suggesting they are making a profit from this practice, or else they wouldn't continue the mining. Therefore, the value of sequestering carbon on their land must be at least equal to the current value they are receiving from their conventional practices, and probably has to be substantively greater in order to induce changes in technologies and sequestration practices.

We have found that most farmers are dually motivated, pursuing both more profits and the good things that come from being responsible in their use of environmental technologies and practices (see Lynne et al., 1995; Lynne and Casey, 1998). Most farmers jointly seek satisfactory outcomes in both the material and moral realms. This is to say, appealing to farmers and ranchers to do-the- right-thing and sequester more carbon could well increase the amount of carbon sequestered, but only if sufficient profits are also generated by the new practices such that it becomes financially feasible. We expect this will be the case in the matter of carbon sequestration as well, even though we need an increased commitment on behavioral research designed to deny this contention.

What kinds of values will likely be generated in the markets, or in government green payment programs? The Office of the Chief Economist (1999) suggests that a carbon emissions allowance might trade for $14-23 per metric ton by 2010. Without trading, a U.S. Department of Energy study (Edmonds *et al.*, 1997) suggests a cost to the economy of $108 per metric ton. This suggests a range of $14 to $108 per metric ton, or around $13 to $98 for a 1-ton emissions allowance. We would expect the value of a carbon offsets in storage certificate representing 1-ton in storage to at least be highly correlated with the emissions allowance price in that a buyer would have the option of buying an allowance or vying, instead, for storage. It may be important to keep in mind, however, that these estimates are from simulation models. As we learned in the sulfur allowances markets, the simulators tended to greatly overestimate the actual prices that have emerged in the actual markets (see Lynne and Kruse, 2001).

Intriguingly, Nebraska could probably play a substantive role in the overall national picture due to Nebraska being a major agricultural player, generally ranking fourth in the Nation in farm sales value. Current estimates on the potential for carbon sequestration show that U.S. cropland has an overall potential to sequester 75-208 million metric tons of carbon equivalent per year (MMTCE/yr). If these numbers were realized, this would be 8 percent of total U.S. emissions of green house gases or 24 percent of the proposed U.S. emission reductions under the Kyoto Protocol (Lal et al., 1999). Paustian et al. (1977) estimated that for a field planted in a corn-soybean rotation in Iowa, converting from conventional till to no-till could increase carbon storage rates by about

550 kg/ha/yr (about 0.25 tons/acre). Potential increases in Nebraska soils are likely to be similar.

In the entire U.S., conservation tillage which is the main way to increase the amount of carbon in storage was practiced on 109 million acres of U.S. farmland in the year 2000. This is around 36% of total planted area, an increase from 26% in 1990 (Frederick, 2001). No-till farming was practiced on over 52 million acres, an increase of over 300% from 1990 numbers (Frederick, 2001). Numbers for Nebraska show relatively even more conservation tillage, perhaps over 50% of the cropland represented in over 8 million acres. As a result, considering that conservation tillage is classified as tillage practice that leaves above 30% residue on the surface, the potential for increased carbon storage in the soil is definitely present because residue cover could be increased to 100% (Frederick, 2001).

Also, to place the 8+ million acres number in perspective, Nebraskans farm and ranch 46.4 million acres or 96% of the state's land area. About 23 million acres are rangeland and pasture land, with about half in the Sandhills area. This leaves slightly over half of the 46.4 million in crops and other uses. A total of 19.4 million acres were harvested in 1999. About 8.1 million acres, mainly corn and soybeans but also including such things as sugar beets and some hay crops, are irrigated. So, we have around 1/3 of the cropland under conservation tillage, which is about the same amount of land that is currently irrigated, and about 1/2 of all the agricultural land is already in rangeland and pasture land. This is to say, we are already sequestering and storing in place substantive amounts of carbon on 2/3 of the agricultural land (the conservation tillage cropland plus the range and pasture land).

In thinking about converting the remaining 1/3 of the land to conservation tillage; moving to no till and upwards of 100% residue on a larger proportion of the conservation tillage land; or, moving more acres of cropland to grass such as through the conservation reserve program, we need to consider the financial and behavioral realities at work. There may be reasons other than that of sequestering carbon for farmers to convert or not convert from conventional tillage systems to conservation tillage and no-till, or to move cropland into grassland.

First, by using conservation tillage systems, operating costs of farming may well decrease, usually due to saving fuel. Second, in some cases, especially on steeper sloping land, conservation tillage systems will also result in higher yields (Casady and Massey, 2000). For example, in Southeastern Nebraska, dryland corn farmed with conventional tillage has an average yield of 85 bushels/acre, while dryland corn farmed under no-till has an average yield of 90 bushels/acre (Selley, 2001). When this area is farmed under a center pivot irrigation system, a conventional tillage system averages 155 bushels/acre, while no-till yields an average of 160 bushels/acre (Selley, 2001). In this region, a case can be made for a switch to no-till farming based on yield differences.

Third, the risk level may change substantively. Variability in yield may change under conservation tillage, and thus change the variance in profit as well (Day et al. 1998, McCarl and Schneider, in Zeuli, pg. 243, 2000). Studies have shown that farmers view risk as a major factor in not using best management practices, even though they may have been demonstrated, on average, to generate savings in operating costs or more yield. One study found that farmers perceive the risk of changing their practices to exceed $40 per acre (Feather and Cooper, 1995, in Zeuli, pg. 243, 2000). When profits are less certain, a farmer's willingness to participate in a carbon market decreases. So, both sellers and buyers of carbon offsets will face risk in the levels of carbon that can actually be sequestered. There is no guarantee that a certain carbon inflow will be obtained, or that a particular storage level can be maintained. Many variables can affect carbon sequestration, such as extreme rainfall levels or colder than expected temperatures (Zeuli, pg. 244, 2000). In the face of such risks, the challenge to the efficiency of a carbon market is its ability to find a price that attracts enough participants into the market and at the same time keep the total costs of the market below those that a command and control (or subsidy) policy would entail (Zeuli, pg. 244, 2000).

Fourth, moving from crop to pasture land could represent substantive losses in revenue and profit. Prices high enough or government payments large enough to shift land use out of such profitable crops as irrigated corn and soybeans to pasture and rangeland in order to sequester more carbon are not likely. We have to keep in mind that we add value to a substantive amount of the corn produced on millions of acres in Nebraska with the livestock feeding industry. Eliminating substantive acreages currently under crops, especially corn, would eliminate or greatly impact a very large livestock feeding industry as well. Also, some people are ranchers and some are farmers; individuals do not easily cross these lines. It is not likely that some crop farmers would ever switch only to pasture (and the livestock operation that would have to result), no matter the price of carbon offsets.

This does not mean, however, that carbon offset prices could not be high enough to change some practices and technologies used in cropping operations. Also, some marginal cropping areas might also be switched to carbon storing crops such as pasture and range even with modest carbon offset prices for carbon stored.

Finally, we also face many potential implementation obstacles beyond the farm level. Potential food shortages in the future may require more acres to be cropped. Insect damage to crops may require more pesticides/ insecticides which could increase the amount of hydrocarbons used. Weed infestation in crops could increase if the amount of acres farmed in no-till increases, and thus pulling more land back into production. On the positive side, it is also possible that higher concentrations of carbon in the atmosphere could reduce the need for bringing more land into production. Some evidence exists that crop yields may actually increase from higher levels of carbon dioxide in the atmosphere. In this case, sequestering carbon and holding it in storage could work counter to the positive effects of more rapid plant growth and higher yields, suggesting an intriguing play as between the corn market and the carbon storage market, with farmers reacting to relative prices.

Could Nebraska Compete in a Global Carbon Market?

Perhaps the most critical aspect regarding Nebraska's ability to compete in a global carbon market is whether payments will be rendered for the amount of carbon stored in stock in the soil or only for the amount of increase in the net inflow into the soil. With over 2/3 of Nebraskas' acreage currently holding substantive quantities of carbon, payments or prices only for new adoption of BMPs or for accretions to the carbon stock will benefit only a very few of the farmers and ranchers in this group. Also, as noted earlier, if farmers and ranchers are not rewarded for already having stored substantive amounts of carbon, a perverse incentive would be created where it could well benefit them to plow out the land, thus releasing the stored carbon, and then receiving payments or being able to sell carbon offsets in flow, and starting again to build carbon in storage. It follows that if a carbon offsets market; a best management practice market; or payment system, is to establish and maintain its moral integrity, payments perhaps are best based on the total amount of carbon stored in stock. This seemingly holds the most potential to be a just and fair way to handle such a payment or market in that those who have been storing carbon for years are then rewarded for doing so, and will have an incentive to keep doing so. Those who have been instead mining carbon will now also have an incentive to build the store of carbon in the soil. By focusing on the carbon stored in the land we are perhaps best positioned to reach a jointly moral and economically efficient solution to the problem.

Also as alluded to earlier, another variable that may have to be considered is the number of years it will take to reach full storage capacity in a particular soil and place, as demonstrated in Figure 1. Once storage capacity is reached, farmers would need to receive payments or be able to continually re-sell the carbon offsets in place to maintain the stock. Thus, the critical aspects are the amount of time soils can sequester carbon before the capacity is reached, and the amount that sequestered carbon held in place will be worth over the longer run. It is not definitely known at this point what these will be: We only know that payments for sequestering carbon for a set period of time must be *at least* as much as the cost incurred, including the opportunities foregone from mining carbon, in the process of sequestering and maintaining the carbon stock.

The answer to the question of whether Nebraska can compete also depends on the extent of the market. If the entire global economy eventually has to offset emissions during the next 20-30 and perhaps up to 50 years with carbon storage, all suppliers, including Nebraska farmers and ranchers, will likely be able to sell storage at a profit. If only modest limits are placed on few emitters (e.g., only the power plants), perhaps other low cost supply areas such as Costa Rican rainforests would quickly saturate the market in offsets. Also, as with all commodities, and no matter the extent of the market, the profit margins will generally vary widely. For example, storing carbon in a rain forest will perhaps always be less costly than storing the same amount of carbon in an area being intensively farmed.

Yet, Nebraskans seemingly will still be able to earn enough profit from the changed practices to make it worthwhile. Like with all commodities, profitability per unit supplied depends on the price or payment being made available to the suppliers relative to the costs of providing said commodity. Cost and return studies for various carbon technologies leading to varying levels of storage in Nebraska's agricultural land need to be done, and possibilities examined.

Stages in the Progress Toward Market Trading

Humans tend to build mechanisms to handle problems on a natural progression involving four fundamental types of social organization. Fiske (1992) sees the progression through four kinds of more elemental social organizations often culminating in market pricing types of mechanisms:

Communal Sharing → Authority Ranking → Equality Matching → Market Pricing

The arrows suggest the one-way movement over time toward market pricing, although it is the case that we also tend to move back and forth on this continuum as conditions warrant. Also, the arrows are meant to mean that oft times salient elements of earlier types of organization may be brought along into the later stages in the evolution. The moral fabric pertaining to just and fair interactions as evolved in the communal sharing stage, e.g., may be embedded in the understructure of the market formed in the market pricing stage. As Kuttner (1999, p. 349) argues, we cannot presume that markets will never be instruments of private tyranny. Safeguards need to be built into the underlying foundation on which any new carbon storage market will rest.

With respect to carbon emissions and carbon storage, we start at some early time in the communal sharing mode, which describes the situation to date, wherein most everyone is emitting substantive amounts of carbon without regard for each other or for the capacity of the natural system to absorb the carbon. At some point, we start to see the problems we are causing for ourselves and the natural system, so we ask some government agency to help to solve the problem as we enter into the authority ranking stage. That is, we see the efficacy of strong centralized, and direct controls on carbon emissions, in order to move directly and quickly to some solution, and ask an agency like the U.S. Environmental Protection Agency to take charge. Later, we see that some "tit-for-tat" strategies might work better, such as represented in carbon banks, with some perhaps depositing carbon offsets and others taking draws on the offsets, in the equality matching stage.

In the final market pricing stage, we see the evolution of trading in carbon emissions allowances and in carbon offsets representing carbon stored in place. We may keep the common ownership of the capacity of the atmosphere to absorb carbon from the communal sharing stage intact, but start to realize that government cannot solve the problem alone as in the authority ranking stage. Yet, we may recognize a legitimate role for government, and keep the central government agency from the authority ranking stage involved in order to set the caps; we may keep the carbon bank from the equality matching stage to help transactions; finally, we may introduce carbon allowances for trade in the emissions market while we introduce carbon offsets in stock for trade in the storage (sequestration) market. Over time, even more complex mechanisms evolve as the two kinds of markets start to interact.

What stage are we currently in? What progression over what period of time might we expect? Drawing on both Fiske (1992) and Colby (2000, esp. Figure 1 on p. 652), we are about to enter into Fiske's authority ranking stage which is roughly the end Colby's Stage 2, all of Stage 3, and positioning ourselves for Stage 4 as depicted in Table 1. We are currently a considerable distance in time and place from the end state of market pricing and trading in emission allowances and in carbon offsets.

Yet, if current legislation before the 107th Congress that places emission caps on power plants (In Senate bill S. 556 and House bill H.R. 1256) is passed during this session (see Lynne and Kruse, 2001), we could move rather rapidly into Fiske's equality matching stage, and into Colby's Stage 4 on our way to market pricing and well functioning carbon markets in Stage 5. Recall that from the time of passage of Title IV to the 1990 Clean Air Act Amendment, it was only about 3-years before sulfur allowance markets emerged (see Lynne and Kruse, 2001). Just now, in the year 2001, the sulfur market is starting to operate quite effectively, suggesting that perhaps it will take about 10-years to reach market pricing in Stage 5 once the carbon emission limits are set in the late part of Stage 3 and the early part of Stage 4.

Conclusions and Final Considerations

Overall, the macro forces at work in the legal, regulatory and economic realms of the carbon question point toward the evolution of some kind of carbon market. It seems reasonable to expect that we will eventually see carbon allowance markets not unlike that used for handling the sulfur emissions problem. It would follow that if such carbon allowance markets emerge, we will also likely see markets in carbon offsets, represented by certificates documenting the stock of carbon stored in the agricultural operation. We could also see a market in carbon offsets in net inflow emerge, although this creates incentive problems in maintaining stocks in place. Also, some believe that we might see markets emerge in best management practices, i.e., farmers signing contracts to farm in certain ways, using certain verifiable practices and technologies. We question that either payments or markets in carbon inflows or in best management practices is workable. We suggest that the focus needs to be placed on carbon offsets representing stocks of carbon actually in storage in the land.

Considerable uncertainty about when, where, and how much marketing will emerge also exists, however, due to widely differing views about how to handle the global warming and carbon problem, or even if there is a problem. The problem in predicting the progress is that we may remain in the communal sharing, Stages 1 and 2 arena for quite some time. Moving out of these stages only becomes possible after we decide that global warming is a real issue needing caps set on carbon emissions. Many members of theU.S. Congress are still of this mindset; perhaps many Americans including most Nebraskans are also of this inclination. Also, there is a tendency to resist leaving the authority ranking stage once the government has been put in charge to solve the problem. We always see resistance to let go, to release and decentralize. The point we often miss in the ongoing dialogue about this problem is that both the government and the market need to play legitimate roles. The public policy experiment that is the sulfur allowances market verifies this contention. The difficult problem we face is predicting when these perspectives might change, if at all, and thus predicting when behavior will change to taking some action to set emission limits and then, next, give flexibility back to individuals to choose options on how to solve the problem at the local level. Without limits set by government and without decentralized flexibility for individuals, there will be no carbon storage market, in either emission allowances or carbon stored. It also questionable that green payments will be effective without this recognition of a joint role for the government and the market.

Unfortunately, providing green payments for conservation could actually run counter to, and reduce the probability of, new carbon markets. With heavy public subsidy, there is no reason for the private sector to help with market solutions. Also, world negotiations relating to setting greenhouse gas emissions limits could break down even further (See Lynne and Kruse, 2001), although the mood seems to be one of doing something about the carbon problem, which generally means that some limits would need to be recognized, and asking the market to be an ever larger player in global interaction. . More specific considerations include:

First, we perhaps cannot emphasize enough the need to focus on carbon offset in stock (COIS) rather than carbon offset in flow (COIF), or best management practice (BMP) markets, the latter two reflecting only changes in the storage or in the practices used by farmers and ranchers. We see the COIS certificate, with each certificate perhaps representing 1-ton of carbon in place, as defining the carbon commodity that Nebraskans would provide for sale on the market, or receive green payments to supply.

Second, we need to face the aggregator problem. Some vehicle may need to be found for bringing smaller suppliers together in order to provide viable quantities of COISs for sale, although current and emerging information technology using internet and web communications could make it feasible for even small numbers of COIS certificates to be bought and sold. It is already being done in the sulfur allowances market: Even individuals can buy and sell small numbers of allowances, as small as 1-ton at a time. This is perhaps the ultimate in a democratic market, wherein individuals can participate and influence the direction of the market.

Third, some means is needed to certify the carbon is indeed in place, both at the outset and in re-certification periodically through the years of the buying and selling of the COIS for a particular tract.

Fourth, consideration could be given to establishing a Nebraska Coalition not unlike the Montana Coalition, an entity with an executive director and a small staff dedicated to bringing units of COIS certificates and their related tracts of land together into viable units. Alternatively, the Nebraska Natural Resource Districts could be the aggregators, although alternatively the NRDs could perhaps play a certifier's role. The Nebraska Department of Natural Resources could also conceivably play a role, perhaps as a central repository for recording carbon trades. In considering this matter, however, we need to not preclude the possibility that private firms could also enter the certifying and aggregating, as well as brokerage and market information business. Some already have so entered on the international scene, and due to this ultimately being a global market, perhaps this is as it should be. Yet, opportunities will also exist for local, Nebraska firms.

Fifth, research needs to be encouraged on determining the specific design of mechanisms to bring about and maintain the storage. This research might best take the form of a case study aimed at developing a simulation to explore how an actual market in carbon offsets in stock (COIS) certificates might operate. Particular attention needs to be placed on ensuring that a moral dimension is explicitly built into the foundation of the mechanism. This dimension would ensure a just and fair mechanism whether of a market or government payment format. If the simulation goes well, actual trading in carbon offsets might be tried on a small scale, test basis.

Another altermative would beto commission cost studies focused on assessing the price at which Nebraska suppliers of carbon in storage can compete on the emerging global markets. Knowing the cost structure could put Nebraskans at a competitive advantage in negotiations for trade.

Sixth, it is fortunate that Nebraska to date has been proactive in addressing the carbon question. The Nebraska Unicameral had the foresight in the year 2000-2001 session, through LB 957, to create the Carbon Sequestration Advisory Committee, and to ask for a background paper on the legal, regulatory and economic questions. We need to continue the progressive steps already taken to ensure that Nebraskans can be players in national and international arenas as the carbon question is addressed world-wide, and work to influence how the problem of carbon driven global warming is solved.

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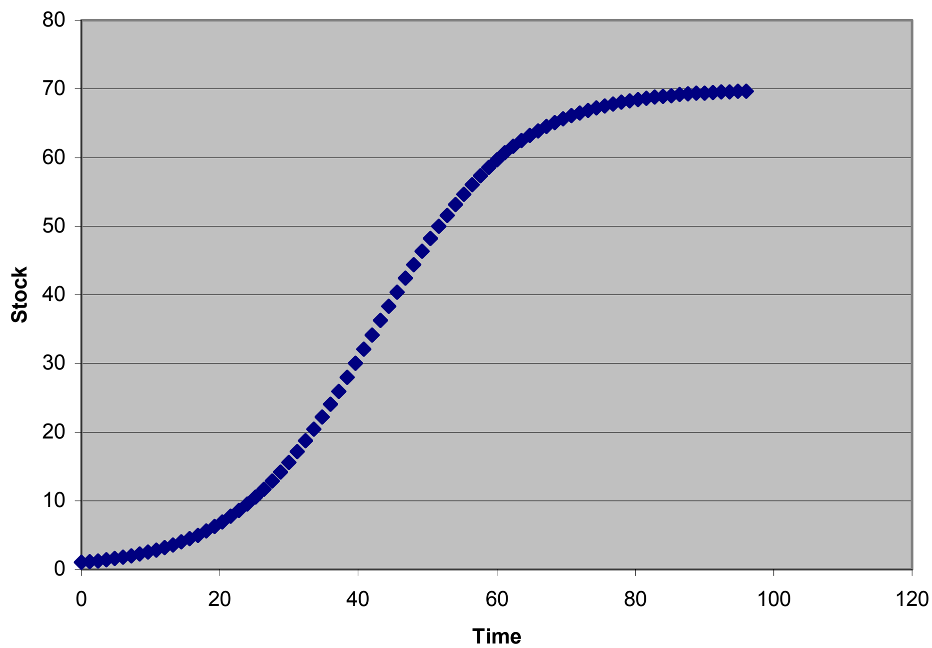
Table 1. Stages in Implementing Cap-and-Trade Mechanisms on the Way to Market Pricing

Fiske (1992)	**Colby (2000)**	
Communal Sharing	Stage 1	➢ Resource abundant ➢ Few conflicts ➢ Informal rights/rules
	Stage 2	➢ Scarcity perceived ➢ Conflicts begin ➢ Debate over proposals to limit use
Authority Ranking	Stage 3	➢ Caps on use, rights allocation, and trading rules proposed and debated
Equality Matching	Stage 4	➢ Caps on use established ➢ Rights allocated ➢ Trading rules promulgated ➢ Cautious trading begins with high transaction costs ➢ Ambiguities in rules/rights create conflicts ➢ Rules/rights clarified
Market Pricing	Stage 5	➢ Trading widely accepted ➢ Active market develops ➢ Transaction costs diminish

Figure 1. Logistic Growth of a Carbon Stock (tons per acre)



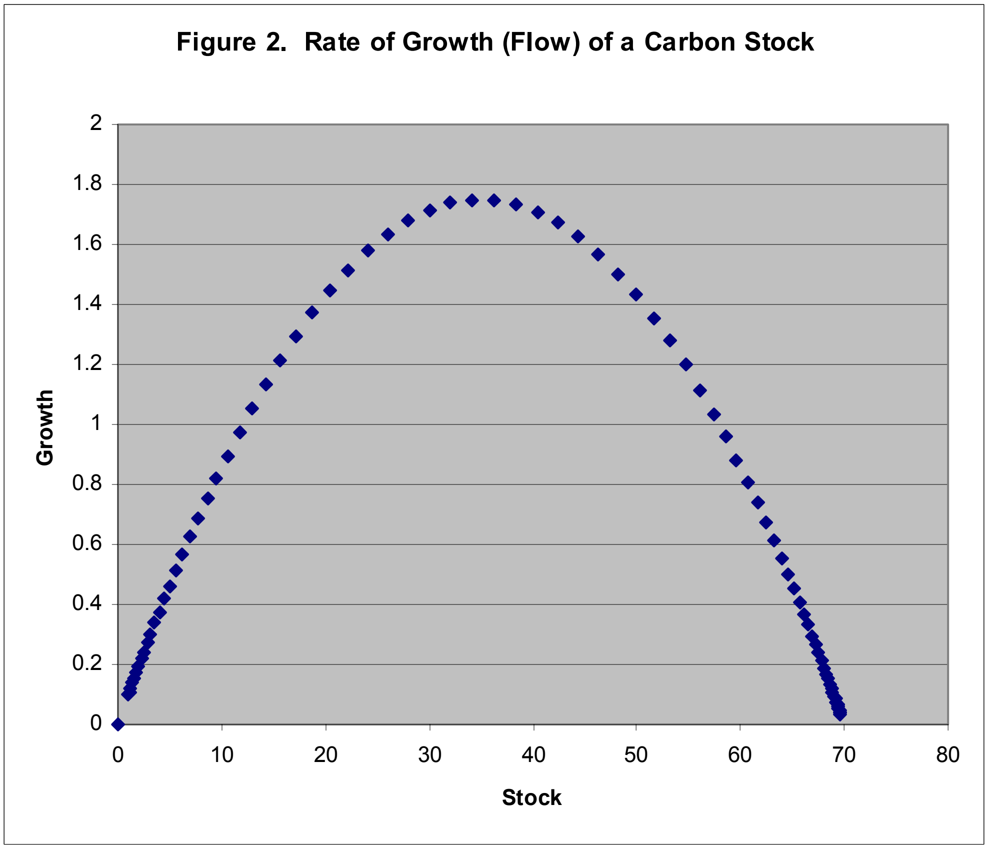


Figure 2. Rate of Growth (Flow) of a Carbon Stock
Growth
Stock
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
10
20
30
40
50
60
70
80