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Sustainable Agriculture for Alaska and the Circumpolar North: Part III. Meeting the Challenges of High-Latitude Farming

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ABSTRACT. Agriculture is a severely underdeveloped industry in Alaska and throughout most of the Subarctic. Growers and entrepreneurs must overcome a diverse set of challenges to achieve greater sustainability in northern communities where resilience is threatened by food insecurity and challenges to northern agriculture have limited the industry. However, several field-based or social policy solutions to problems of high-latitude agriculture have been proposed or are being put into practice. Field-based solutions include the use of special infrastructure or farm management strategies to extend the short growing season, improve soil quality, integrate appropriate pest and irrigation management practices, and further develop the livestock sector. Social and policy solutions are resolutions or decisions reached by stakeholders and government, often through cooperative interaction and discussion. These solutions stem from meaningful discussion and decision making among community members, organizations, agencies, and legislators. Social and policy solutions for Alaska include addressing the high costs of land and the preservation of agricultural lands; improved markets and market strategies; more appropriate funding for research, education and infrastructure; and other integrative or cooperative efforts. Collectively, these solutions will work to improve the outlook for sustainable agriculture in Alaska.

Key words: Alaska agriculture, farming, high latitude, livestock, market, policy, season-extension techniques, solutions, stakeholders, sustainable agriculture

RÉSUMÉ. En Alaska et dans une grande partie des régions subarctiques, l'agriculture est une industrie extrêmement sous-développée. Les producteurs et les entrepreneurs doivent surmonter un ensemble de défis variés pour donner lieu à une plus grande durabilité dans les collectivités nordiques, là où la résilience est menacée par l'insécurité alimentaire et où les défis caractérisant l'agriculture nordique imposent des restrictions à l'industrie. Cependant, plusieurs solutions apportées sur le terrain ou par le biais de politiques sociales vis-à-vis des problèmes touchant l'agriculture en haute latitude ont été proposées ou sont en train d'être mises en pratique. Parmi les solutions apportées sur le terrain, notons le recours à une infrastructure particulière ou à des stratégies de gestion agricole visant à prolonger la courte saison de croissance, à améliorer la qualité du sol, à intégrer des méthodes de gestion de l'irrigation et des organismes nuisibles, et à mettre davantage l'accent sur le secteur de l'élevage du bétail. Les solutions en matière de politiques sociales prennent la forme de résolutions ou de décisions prises par les parties prenantes et le gouvernement, souvent en collaboration et à la lumière de discussions. Ces solutions découlent de discussions et de prises de décisions importantes entre les membres des collectivités, les organisations, les agences et les législateurs. Les solutions de politiques sociales de l'Alaska portent notamment sur le coût élevé de la terre et la conservation des terres agricoles, sur l'amélioration des marchés et des stratégies de commercialisation, sur la nécessité d'obtenir des sources de financement plus adéquates pour la recherche, l'éducation et l'infrastructure, ainsi que sur d'autres efforts d'intégration et de coopération. Ensemble, ces solutions permettront d'améliorer la conjoncture de l'agriculture durable en Alaska.

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Mots clés : agriculture en Alaska, agriculture, haute latitude, bétail, marché, politique, techniques de prolongation de la saison de croissance, solutions, parties prenantes, agriculture

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> There are two spiritual dangers in not owning a farm. One is the danger of supposing that breakfast comes from the grocery, and the other that heat comes from the furnace.
>
> (Leopold, 1949:6)

INTRODUCTION

Nearly any crop can be grown in Alaska. The challenge is making it profitable and sustainable. Limitations and hindrances to sustainable agriculture at high latitudes can sometimes be mitigated through the use of field-based solutions. Such improvements generally include using specialized infrastructure or farm management practices that are appropriate for local environments, using resources more efficiently to improve soils and lower costs, and finding ways to stretch the short growing season. However, while improving yields or finding ingenious ways to extend the growing season are attractive, they will do little to resolve some of the more intractable issues that limit the agriculture industry in Alaska and some regions of more northern countries. These issues require social and policy solutions that incorporate stakeholder and government input and cooperation. For instance, how will agricultural land be conserved or made more available and affordable to growers? What marketing and marketplace solutions are available for northern growers, and how are these changing in the modern age? What changes to funding programs will be needed so that more Alaskan growers can benefit from them?

These and other solutions are needed because Alaska and several circumpolar countries are over-reliant on imported foods, although some are more food self-sufficient than others (Stevenson et al., 2014a). In Alaska, it is probable that more than 95% of all agricultural products and commodities are imported (Stevenson et al., 2014a). Year-round food supply and food storage are also insufficient, given the state's population and geographical separation from the lower 48 contiguous states. Alaska's population is spread widely over a large area, and many communities are isolated. Its communities range from urban to extremely remote; consequently, diets vary substantially and range from almost no dependence upon wild foods (i.e., locally acquired fish, game, and berries) to a very strong dependence upon them. The presence and practice of agriculture and horticulture also vary throughout the state, from small-scale gardening and subsistence agriculture to small farms and a few moderately sized farms; however, most farms are small and lie on the road system.

A suite of environmental, geophysical, biological, and socioeconomic challenges to agriculture exists in Alaska (Stevenson et al., 2014b). Major environmental challenges, which include low average temperatures, a short growing season, and uncertainty of frosts, are obvious and often related to high latitude. Geophysical challenges include sometimes poor soil quality, high moisture content, poor drainage, cold soils, and low nutrient content. Biological challenges can include decreased microbial activity due to cold soils and the influence of various pests, weeds, and diseases. Socioeconomic challenges to farming in Alaska can include low financial incentives or return for farmers, inconsistent to non-existent markets, the high cost of farmland, the lack of suitable infrastructure and inputs, and a lack of cooperatives. For rural farmers, farming competes for time and resources with more traditional means of subsistence food acquisition, and expenses are increased by the high costs of living, energy, and shipping. New farmers sometimes lack the funding, knowledge, or experience required to begin farming in Alaska.

This paper discusses some solutions that are benefiting and advancing sustainable agriculture in Alaska and the circumpolar North (Fig. 1). We review major aspects of what is currently being done to deal with the unique constraints of high-latitude agriculture, both in the field and (perhaps more importantly) with respect to social and policy changes. We also propose some innovative strategies yet to be implemented.

FIELD-BASED SOLUTIONS

Field-based solutions are technical and practical strategies being implemented to improve production in cold regions with short growing seasons. Their goal is to increase returns and generate the potential for improving year-round food supply.

Note that the terms "sustainable agriculture" and "organic agriculture" are not synonymous: many sustainable practices are not organic, and many organic practices are not sustainable. Rather, the major goals of sustainability are that the practices be socially acceptable and economically viable, preserve limited resources, and do not pollute the system. Some of the best production practices in Alaska, whether conventional or organic, meet these criteria. The aim of sustainable agriculture is for the entire farming system to work toward these goals—although they are only goals, as we are unaware of any production system in the Subarctic that achieves true sustainability.

The Advancement of Season Extension Techniques

Farmers and gardeners in Subarctic and even a few Arctic regions around the world must contend with the short

FIG. 1. Diagram of sustainable solutions to problems that challenge Alaskan agriculture.

growing season that results from a rapidly changing photoperiod in spring and fall, a relatively cold climate, and cold or frozen soils. Season-extending techniques such as plastic mulches, cold frames, high and low tunnels, and greenhouses work by warming soils or the ambient air around the plants, or both. While the use of these structures is neither new nor unique to the circumpolar North, they are invaluable to northern agriculture because of their potential to increase crop yield, minimize pests and disease, and buffer against unpredictable patterns of wind, rain, hail, and temperature change. Solutions must be made on a more localized scale, taking into account local microclimates, topography, soils, other physical factors, and several biological factors. In general, the use of plastic mulch and row covers results in a vegetable harvest that is one to three weeks earlier, and the yields of some crops (e.g., cabbage, zucchini squash) can be two to five times higher when using plastic mulch (Purser and Comeau, 1990; Purser, 1996). Season-extension techniques help some warm-season crops to grow in a cold or unpredictable environment (Waterer, 2003) and can make the difference between a harvestable crop and zero marketable yield (Purser and Comeau, 1989; Maurer and Frey, 1990). For example, Tim Meyers, a local farmer from Bethel, Alaska, has stated:

> [Our] greenhouse soil temperatures are 70˚F just by running a fan and insulating the floor. The structures are heated up quickly by the sun in the morning because of the plastic coverings and steel frames, and the earthen beds and ventilation system allow them to hold a lot of heat through the night.… Raised beds and plastic lining elevate the soil temperature 8 to 10˚F and allow our outdoor produce to continue growing successfully …; wire-framed plastic coverings are important for this region, which can have a large number of windy, rainy, and cloudy summer days. The coverings insulate the crops and provide protection from the elements that would otherwise negatively affect crop production.
>
> (Stevenson, 2009:28–29)

Many elements of sustainability can be captured in greenhouse production. As Alaskan produce growers depend on plants started in greenhouses for many crops, improvements in the efficiency and sustainability of the nursery industry would affect the agriculture industry as a whole. Klock-Moore (1999) found that plants grown in compost made from biosolids and yard trimmings were larger than plants grown in conventional potting media or compost made from greenhouse substrates and yard trimmings. In Fairbanks, Alaska, sewage sludge is composted and approved for residents to use on vegetables and in the landscape (Joling, 2006). Greenhouse owners in the northeastern United States, who still face thermal challenges although they are at lower latitudes, have used a variety of energy-saving techniques such as energy curtains, bottom heat, tightening of the greenhouse, new wall materials, environmental control computers, growing in less space, and growing hardier plant varieties (Brumfield, 2010). In China, single-slope, solar greenhouses are sometimes used to produce vegetables successfully year-round without supplemental heat; the walls of these greenhouses are insulated except on the southern side, and sometimes they are even semi-underground (Gao et al., 2010). Such greenhouses would not make year-round production possible without

FIG. 2. A low tunnel in Fairbanks, Alaska. (Photo: Heidi Rader.)

FIG. 3. High tunnels in Fairbanks, Alaska (Photo: Heidi Rader.)

supplemental heat in most regions of Alaska, but experimentation with design could reduce heat costs in the spring and fall.

Elements of greenhouse design, lighting, heat flux, and fan use have been reviewed or discussed previously by other authors (Brown et al., 1986; Jahns and Smeenk, 2009; Seifert, 2009; Stevenson, 2009). Operating a greenhouse during the typical Subarctic outdoor growing season (May – September) requires no light supplementation, although supplemental light can be used to increase plant growth during low light levels and to manipulate the length of the photoperiod. Fluorescent lights produce more efficient and linear light than incandescent bulbs (Jahns and Smeenk, 2009) but are still appropriate only for seedling production. Full-spectrum lighting is required for flowering and fruiting plants, and some new LED lighting technologies meet spectrum requirements while minimizing electricity costs.

Some greenhouses, such as those found on the Meyers farm in Bethel, Alaska, contain innovative construction that is well-suited to high latitudes, including steel framing, underground insulation of the dirt floor, automatic ambient temperature control, and a space-saving layout (Stevenson, 2009). By using many of the season-extension techniques discussed in this section, the grower has been able to claim, "Our farm provides people with twice the amount of vegetables at half the cost of supermarket produce that's flown in… and ours is all organic" (Stevenson, 2009:28).

Plastics in northern agriculture carry a moderate to high initial investment cost, but are likely to result in more consistent and sustainable positive outcomes. These can include a more efficient use of fertilizer and water, reduced soil erosion, a cleaner and more uniform crop, reduced leaching, easier weed control, greater transplant survival, and reduced cold injury (Purser, 1996). The use of plastics in Alaskan farming has been discussed by other authors (Purser and Comeau, 1989; Purser, 1996; Rader, 2006). Black plastic provides excellent weed control and also warms the soil, although not to the same extent as clear plastic. Low tunnels are long, single-row, hemi-hoop framed structures covered by plastic (Fig. 2) that are often used to protect plants from direct exposure to the elements and increase air temperature (Wells and Loy, 1985). Low tunnels have been used successfully on and off the road system, even in remote areas such as Bethel, Alaska (Stevenson, 2009), and the Kobuk River region (Dearborn, 1979).

High tunnels are structures both taller and wider than low tunnels and often large enough to accommodate a tractor (Fig. 3). They represent a field-based season-extension technique that allows routine activities such as weeding, ventilation, and harvest to proceed with minimal additional labor, both in Alaska (Rader, 2006) and at lower latitudes (Wells and Loy, 1993; Wittwer and Castilla, 1995; Burkhart and White, 2003; Lamont et al., 2003; Waterer, 2003). Interestingly, weed populations in temperate regions have been shown to be lower in high tunnels than in open field areas (Waterer, 2003) because the exclusion of rain and more prolific use of drip irrigation inside the tunnel facilitate the regulation of soil moisture.

Like low tunnels, high tunnels provide shelter and a protected environment for plants. In Alaska, their protection has been reported to improve the quality of lettuce plants with limited necessary preparation or marketing loss compared to field-grown lettuce (Rader and Karlsson, 2006). At high latitudes, a plant environment warmer than outdoor temperatures and shelter from winds are important benefits of high tunnels (Wells and Loy, 1993; Wittwer and Castilla, 1995; Hodges and Brandle, 1996). Wind can increase transpiration rates, lodging rates, and nutrient loss while decreasing crop growth, photosynthetic efficiency, and pollination rates (Bagley and Gowen, 1960; Biddington, 1986; Hodges and Brandle, 1996). Even at lower latitudes, shelter from the elements in high tunnels can increase the quality and reliability of produce (Wells and Loy, 1985; Wittwer and Castilla, 1995; Jahns, 2005). The dependable protection provided by high tunnels is especially important in areas like Alaska where climate patterns are difficult to predict and represent (see Stevenson et al., 2012).

TABLE 1. Some costs and benefits of using season-extension techniques at high latitudes.

	Plastic mulch	Frost cloth	Low tunnels	High tunnels	Automated greenhouses
Material or building cost	Low	Low	Low	Moderate	High
Heating and ventilation cost	None	None	None	Low	High
Supplemental lighting cost	None	None	None	None	High
Frost protection benefit	Low	Low	Low	Moderate	High
Temperature increase modification benefit	Low	Low	Low	High	High

The early maturity and high-quality produce achieved in high tunnels can compensate financially for otherwise lower-value crops (Wittwer and Castilla, 1995). In Saskatchewan, higher yields of muskmelons, peppers, and tomatoes have been achieved in high tunnels as opposed to low tunnels (Waterer, 2003). By extending vegetable production, high tunnels can reduce the overall demand for fresh produce to be shipped from transnational and international sources to Alaska later in the season, thereby improving direct market relationships and opportunities.

When growers start with disease-free plants, high tunnels can help maintain an insect and pest-free environment (Wells and Loy, 1985; Wittwer and Castilla, 1995; Lamont et al., 2003). Over three growing seasons, Waterer (2003) used no pesticides in high tunnels but had minimal problems with disease and insect pests. Furthermore, the use of drip irrigation systems in high tunnels can increase water efficiency and sustainability, improve produce quality, reduce weeds (Wittwer and Castilla, 1995), and minimize the need for herbicides (Wells and Loy, 1993; Lamont et al., 2003; Waterer, 2003). High tunnels are not usually heated or ventilated automatically, so the growing environment can be highly dependent on manual labor; however, mechanical removal of weeds and herbicide treatment may be easier in high tunnels.

While it is important to evaluate crops on the basis of their value and general temperature requirements, cultivars should also be selected for favorable responses to high tunnels (Wells and Loy, 1985). For example, certain types of lettuce have been shown to be more prone than others to bolt in high tunnels (Zhao et al., 2003). Higher yields could be achieved by grouping crops in a tunnel according to optimum temperature requirements, which also may vary with stage of growth (Waterer, 2003).

While high tunnels and greenhouses share several similarities, they provide different economic benefits. In the months when the high tunnel is empty, the greenhouse can be productive. Likewise, in the shoulder seasons when a high tunnel is just able to keep the frost from killing a crop, the greenhouse, by maximizing use of all naturally occurring sunlight as a high tunnel cannot do, can be at full production. This flexibility justifies the additional expenses of a greenhouse. Greenhouses at high latitudes maximize the length of the growing season by buffering against frosts in early spring and late autumn. Plants seeded in greenhouses in the final rotational round of summer may never be transplanted to the field and often instead remain protected in greenhouses into fall. In that sense, the greenhouse season in many parts of Alaska runs from March to October (MSB, 1983).

Greenhouse costs vary considerably depending on the permanence of the structure and the level of automation and control. Start-up and operation costs are significantly lower for high tunnels than for commercial greenhouses. For instance, a greenhouse can easily be 10 to 20 times more expensive than a high tunnel (although prices range significantly depending on location, type of greenhouse, and degree of automation). Simple overwintering houses with minimal heating capability can be half the cost of quonset-style poly greenhouses with heating and cooling capacity because fully automated greenhouses can have additional costs related to taxes, fuel for heating, electricity for ventilation or lighting, and higher labor costs for planting in pots.

High tunnels are not taxable (i.e., assessments should not increase) because typically they are not considered to be permanent structures: they are not heated, are manually ventilated, and can be tilled with a tractor. Early advocates for high tunnels opted to refer to high tunnels as "Economic Development Units" because they were used to produce a wide variety of horticulture crops throughout the year with a low initial capital investment (Wall, 2000). The U.S. Department of Agriculture's Natural Resource Conservation Service (USDA NRCS) reimburses producers for a significant portion of the cost of high tunnels as part of its Environmental Quality Incentives Program (EQIP) (USDA NRCS, 2011).

High tunnels can be more cost effective than low tunnels at lower latitudes (Hochmuth et al., 1993; Waterer, 2003; Rowley et al., 2011; Table 1), but it is not yet certain that this is true in high-latitude communities. As land and energy prices rise, high tunnels should become more economically viable (Wittwer and Castilla, 1995). Aberrant weather, especially early and late frosts, should have less of an impact where high tunnels exist, and direct market opportunities should increase early and late in the season, when the overall supply of local produce is lower, as is true at lower latitudes (Gent, 1991; Wells, 1991; Lamont et al., 2003).

Improvements to Soil Quality and Nutrient Content

Cold soils, excessive or inadequate rainfall, and poor soil conditions can all limit or reduce food production in Subarctic areas (Stevenson et al., 2014b). What solutions are currently in operation or under experimentation to address these issues? In Fairbanks, Alaska, ridge tillage on level plots influences radiation absorption. Ridge-tilled or raised beds oriented north to south and having a slope of 20° to 40° can absorb more solar radiation than others (Sharratt et al., 1992). Although rare and management intensive, terraces constructed on north- or south-facing slopes can improve the agricultural efficiency of land and limit soil erosion. The selection of south-facing slopes to start small farms is not uncommon, as is seen near Ester, Alaska (Mudd, 2005). South-facing slopes can be used to intercept the sun's rays at a directly perpendicular angle, rather than losing reflected light, resulting in higher temperatures, less extreme temperature variations, and earlier snowmelt. Attention to solar angle can also maximize the sun's influence on plant growth, although this may be a minor detail and is not always considered by growers. Partially shaded areas or north-facing slopes can accommodate crops with a preference for cooler temperatures (e.g., cabbage, broccoli, spinach, radishes, leaf lettuce), while south-facing slopes or areas in direct sunlight most of the day can be reserved for crops that tolerate brighter and warmer conditions (Roberts, 2000).

Since soil temperature decreases rapidly with depth, directly seeded vegetables are usually planted more shallowly in Alaska than at lower latitudes. Seed soaking is also used to accelerate germination, especially in peas and beans. Generally, plants at high latitudes are often seeded as early as it is safe to do so to maximize the short growing season. The trade-off is that seeding too early creates risk of frost damage, while protecting seeds until all danger of frost has passed could mean an even shorter growing period and reduced yields.

Preserving relatively thin surface soils means implementing sound conservation and management principles. It has long been known that nitrogen and phosphorus supplements are needed for farming in Alaska (e.g., Mick and Johnson, 1954), and soil tests can help to recommend site-specific nutrient requirements (some nutrients, such as phosphorus, can persist in soils). Growers must weigh the costs of purchasing and shipping inorganic and organic fertilizers to determine the most effective fertilization strategy for their area.

In soils that are frozen for much of the year, microbial activity and mineral weathering can be minimal, as release of available nutrients from these processes occurs for only a few months each year (Stenberg et al., 1998). Thus natural fertility is lower and more fertilizer is needed. Fertilization requirements, especially nitrogen, are noticeably decreased by fallowing the land (Wooding and Knight, 1973; Chapman and Carter, 1976; Lewis and Wooding, 1978; Husby and Wooding, 1985). Husby and Wooding (1985) report that during the fallow period, soil accumulates or stores nutrients, making it possible for the soil to contribute more of its natural fertility to crop production. Incorporating crop residues into soils in the fall, rather than waiting until spring, can help alleviate nutrient immobilization, the process in which microorganisms feeding on crop residues compete with crops for available nutrients (Lewis and Wooding, 1978).

Composting is a common form of organic fertilizer preparation in Alaska and can include various forms of plant and animal waste. The specifics of composting in Alaska have been reviewed in detail in two relatively recent publications (Rader, 2010; Smeenk, 2011). Growers can use three main types of composting: hot, cold, and worm composting (see Rader, 2010; Smeenk, 2011). The benefits of composting include recycling waste materials that would otherwise be discarded, maintaining and building soil structure, providing major nutrients and secondary trace elements necessary for plant growth, decreasing leaching of nutrients from the plant root zone, protecting against soil erosion, and lowering capital cost (Vandre and Stirrup, 2008; Himelbloom et al., 2010; Rader, 2010; Smeenk, 2011).

Composting in northern regions has unique challenges not found in warmer climates. Cold spells and excessive winds, for example, can slow decomposition rates. Sparse availability of carbon and nitrogen sources is a limiting factor in some areas. For instance, there is an insufficient supply of wood by-products from trees (e.g., sawdust, woodchips, leaves) to mix with fish waste in the marshy flats of the Yukon-Kuskokwim Delta in Western Alaska. Farmers and horticulturists there have been known to collect driftwood from the river to use as a carbon source (Tarnocai et al., 2009).

Fish by-products are commonly used as a protein supplement in the livestock industry, but they are also becoming a popular nutrient source in organic field production. At lower latitudes, integrating nutrients derived from fish or fish waste into agricultural systems during irrigation is common and can reduce the need for chemical fertilizers (Fitzsimmons, 1992; Hosetti and Frost, 1995; Stevenson et al., 2010). At higher latitudes, as in Alaska, small-scale composting that includes fish is common (Anderson, 2011). The potential for fish composting is far greater than is currently being realized. Each year, Alaska's fishing industries generate over one million metric tons of fish by-product (waste) that could be used as fertilizer in agriculture (Betchel and Johnson, 2004). Practical uses have included the application of fish compost, fish meal, or liquefied fish slurry (Zhang et al., 2007; Stevenson, 2009; Himelbloom et al., 2010). Fish fertilizers are especially useful in remote communities that would otherwise pay exorbitant shipping costs to fly in commercial fertilizers, especially organic fertilizers that have less concentrated nutrients (Stevenson, 2009). One drawback, however, is that integrating fish waste into agriculture can attract bears. This problem can be mitigated through the use of specially designed electric fences (Cella, 2010). The USDA NRCS has provided funding for bear fences, paying 75% to 90% of costs for farmers on the Kenai Peninsula (Cella, 2010).

Temperature affects the activity of microflora and the degradation rate of fish by-products. Cumulative mineral nitrogen release is quite similar for various forms of fish by-products. A study of three fish-based fertilizers (protein hydrolysate from salmon, commercial fish meal from Alaskan pollock, and commercial fish bone meal made from Alaska whitefish) measured very similar and non-significant differences in mineral nitrogen release despite differences in protein content (10.9 g N 100 g^{-1} dry matter for fish meal, 6.2 g N 100 g^{-1} dry matter for fish bone meal, and 4.4 g N 100 g^{-1} wet weight basis for fish hydrolysate) (Zhang et al., 2007). All three also showed almost no phosphorus release despite their initial differences in phosphorus content (3.6 g P 100 g^{-1} dry matter for fish meal, 8.0 g P 100 g^{-1} dry matter for fish bone meal, and 1.9 g P 100 g^{-1} wet weight basis for fish hydrolysate). Cumulative mineral nitrogen release from each of these three substances followed a typical two-stage pattern over 56 days of incubation: a fast-release phase for seven days, followed by a slow release phase. The results of this laboratory-based mineralization, carried out at higher temperatures than would be seen in Alaskan soils, can be viewed as a relative measure of the forms of organic matter in the soil. Anecdotal evidence and early studies suggest positive results from application of fish waste slurry or compost (Stevenson, 2009; Himelbloom et al., 2010).

Farms in other circumpolar regions have also used fish waste in agriculture. In Finland, lake fish have been composted with peat, straw, or reed as a potential soil amendment for agricultural purposes (Roinila, 1998). In Canada, salmon farms have composted dead fish with wood by-products to generate an organic fertilizer (Vizcarra et al., 1993).

As mentioned previously, fishmeal may also be useful in production of livestock species (Finstad et al., 2007; UAF CES, 2011a). Alaskan reindeer (*Rangifer tarandus tarandus*) fed either fishmeal or soybean meal showed no significant difference in overall weight gain, although feed conversion efficiency was significantly higher in reindeer that ate fishmeal (Finstad et al., 2007). There was also no difference in meat color, pH, or sensory attributes (i.e., no "fish-related" flavor reported by a trained review panel, despite at least one negative report mentioned in Stevenson et al., 2014a). Interestingly, free-ranging reindeer in these studies showed higher levels of omega-3 fatty acids and polyunsaturated fatty acids than either of the treatment groups.

Manure from poultry, cattle, goats or other animals can be composted or applied directly in spring and halfway through the growing season. Other waste compost is available in Fairbanks and some other cities free of charge. In villages, rabbit, chicken, and even moose droppings can be available as cost-effective sources of nutrients. Moose droppings collected in the months of May and June in Fairbanks have been reported to have fertilizer equivalent values of 2.5% N, 1.8 % phosphate, 1.2% K, 0.6% Zn, 1.6% Ca, and 0.7% Mg (UAF CES, 2010). By comparison, a 1000-pound cow will produce about 15 tons of manure per year containing 1.4% N, 1.3% phosphate, and 1.8% K, although nutrient values are much lower in winter than in summer. Improperly stored animal manures can lose 30% of their nitrogen value in three months and 50% in six months (Sommer, 2001).

In rural areas, several other methods of efficient resource use have been implemented into local horticulture. For instance, local supplies of sphagnum moss have been used to reduce odors and control air and water levels in compost piles, not to mention the added value of increasing organic matter to retain water for plants. Phosphorous and potassium requirements have been met through the use of ash that comes from burning wood and animal bones; bone ash is 22% to 27% phosphorus, while wood ash is about 8% poatassium (UAF CES, 2011b). Biochar, the product that results from burning wood or bones in pyrolysis, could offer even greater long-term benefits to soil by reducing nutrient leaching and increasing water-holding capacity (International Biochar Initiative, 2014).

Cover crops are important for increasing soil fertility and structure. In particular, bacteria found in peas and beans fix atmospheric nitrogen. The bacteria live on small root nodules of legumes and generate a usable nitrogen supply for themselves and the host plant. Little research has been carried out to determine the best practices for using cover crops in Alaska. In warmer climates, cover crops are often planted during shoulder seasons, when a profitable crop would normally not be grown. In colder areas of Alaska, cover crops generally need to be grown during the primary growing season. Planting cover crops between rows can maximize growing space. Generally cold hardy cover crops suitable for the northern continental United States will also be suitable for Alaska and the circumpolar North—especially if grown during the normal growing season. Clark (2007) outlines the pros and cons of various cover crop species, as well as identifying which species are most suitable for different U.S. regions. These data can be used in conjunction with agronomic research done in Alaska (Van Veldhuizen and Knight, 2004); however, more research is needed to identify ideal planting schedules and combinations of cover crops for Alaska.

Although many soils in Alaska are acidic, they vary from acid to alkaline statewide (Stevenson et al., 2014b). Therefore, Extension agents generally recommend testing the soil before directly applying lime. To raise the pH of acidic soils, limestone can be ordered and shipped in to Alaska, but it is expensive. For smaller plots, alternative calcium carbonate materials present locally may be used, such as shell deposits (Roberts, 2000) or ashes of burn pits (Dearborn, 1979); both can be high in calcium and will neutralize excess acids to raise pH.

Soil structure and texture can be improved by adding peat moss, compost, and organic mulches. Soils in some regions have been improved by manually working in a mixture of peat, fish waste, and kelp, known as "fishy peat" (Nicholls et al., 2002). Soil potash, containing potassium, is important to crops in Alaska. Roberts (2000) reported that more than 35 years ago, the commercial potato industry was nearly wiped out in some parts of Alaska because of potash deficiencies. For organic growers, potash sources or mixtures can include plant residues, wood ash, manure and compost, or mineral rock powder. Soil testing is recommended to determine what nutrients may be lacking so that proper supplements can be provided and sustainability improved.

Soil structure and texture can generally be preserved or improved by minimizing tillage activity, as well as by incorporating manure and cover crops. Conservation tillage practices are an important consideration for sustainable farming as they can stabilize soils, eliminate erosion, help to increase the amount of water and organic matter in soils, and benefit soil biota. Long-term data from Subarctic Alaska have been used to determine the impact of two decades of tillage and residue management on a range of physical properties that govern wind erosion (Sharratt et al., 2006a), as well as to assess infiltration, water retention, and saturated hydraulic conductivity of soils (Sharratt et al., 2006b). While "no tillage" appears to be the most effective management strategy for mitigating wind erosion, it is not effective for controlling weeds. It also results in the formation of an organic layer on the soil surface, which has important ramifications for long-term crop production in the Subarctic where the mean annual temperature is below freezing, as well as for the soil hydrological and thermal environment (Sharratt et al., 2006a, b). Furthermore, Sparrow et al. (2003) reported that no-till seeding of most forage crops into declining grass stands is not likely to improve forage yields or quality with existing technology. "Minimum tillage" (i.e., autumn chisel plow or spring disk) appears to be an appropriate and viable management option for reducing erosion and maximizing infiltration (Sharratt et al., 2006a, b).

Irrigation Infrastructure and Methods

Some short-term periods of soil-water deficit occur in most years throughout Alaska, so irrigation solutions are required. In Southcentral Alaska, for example, rainfall is typically low during the early part of the growing season (Bierman, 2005). Sharratt (1994) in models and studies of barley found that water stress was frequent in Interior Alaska and led to significant decrease in yields. A fluctuating water supply characterized by alternating wet and dry conditions promotes water-related physiological disorders in plants, such as blossom-end rot, tip burn, and splitting of fruit, all of which can affect crop prices. Selection of the ideal irrigation systems and appropriate water management regimes are imperative.

Trickle or drip irrigation systems can provide a very effective and efficient means of watering in areas of Alaska that have extended periods of dry weather during the growing season. Aspects of drip irrigation have been discussed by Bierman (2005). Disadvantages to drip irrigation systems, however, include the initial cost of infrastructure and annual installation and maintenance costs.

Despite Alaska's abundant water supply, some rural communities are water stressed and have water-related problems. In some very rural areas, water availability is low, and the cost of water can be quite high. These and other parts of Alaska have much to gain in areas of sustainable water management practices and water conservation through irrigation methods. Greater sustainability in these areas can be achieved by monitoring soil water content using tensiometers and electrical resistance blocks and by developing a water budget based on estimates of evapotranspiration from the soil surface and from plants. The traditional guideline has been to allow soil water to drop to 50% plant available water before refilling the root zone of the crop through irrigation. However, current recommendations are to water when the soil-water deficit reaches 10% to 30% of field capacity (i.e., when soil-water content is 70% to 90% of field capacity) (Bierman, 2005). Drip irrigation can achieve higher moisture content in the root zone of the crop more efficiently than sprinkler irrigation, and targeting the root zone lowers overall water use. In more remote regions, rivers, ponds, and water retention devices may be sufficient water sources for small farms. When rainfall is not sufficient for certain types of crops, small gasoline-driven well pumps may be used to deliver water and keep low availability from limiting plant growth (Dearborn, 1979).

Integrating Specific Pest Management Strategies

The development of the agricultural sector in Alaska is dependent on effective management strategies for insect pests, weeds, and disease. There are some known challenges in controlling pests that infiltrate Alaskan farms (Stevenson et al., 2014a), although knowledge of agricultural insect pests, weeds, and diseases in the circumpolar region is lacking, and their occurrence and biology are poorly understood (Pantoja et al., 2009, 2010a, b). Furthermore, agrochemicals used to kill pests, weeds, and disease can linger in the soils of cold environments longer than in warmer areas because the activity of soil bacteria to degrade them is generally slower in colder areas. For these reasons, individual management tactics that can be integrated into insect pest management programs have been used in Alaska.

Research conducted from 2004 to 2006 in the main potato production areas of Alaska resulted in the documentation of species composition, abundance, and incidence of pests—for example, 41 leafhopper species, associated with agricultural settings—and the best time to sample them (Pantoja et al., 2009). The information on aphid abundance can be used to move planting dates to avoid aphid incidence, although because of the short growing season, it is not known if this practice will be feasible in Alaska. The ladybeetle, a known aphid predator, is commonly used in many areas of the United States. Usually, ladybeetles are released in large numbers to control pests in confined areas, such as greenhouses. Additional information is needed to augment numbers of naturally occurring ladybeetle species in Alaska and exploit this sustainable method of aphid control. One species introduced to Alaska, *Coccinella septempunctata*, has displaced native species in other agriculturally important areas of the United States (Wheeler and Hoebeke, 1995; Elliot et al., 1996; Alyokhin and Sewell, 2004). This fact emphasizes the need to better understand native fauna before implementing biological control programs.

Growers use floating row covers and plastic tunnels, discussed above, to manage incidence of leaf miners, cutworms, and root maggots. Grasshoppers are pests of small grains, especially barley and canola (Begna and Fielding, 2003, 2005). Costs of insecticide application in Alaska have been estimated at 32.00 U.S. dollars/ha (Begna and Fielding, 2005), making chemical control of grasshoppers cost-prohibitive except in extreme cases. Prevention or at least minimization of outbreaks is much more economical and environmentally desirable than controlling outbreaks. Habitat management tactics that result in a cooler microclimate (e.g., increased shade from shrubs, or cooler soil temperatures from a thick layer of grass litter) may reduce grasshopper populations, but the economics of such practices are unknown.

Many herbicides are currently used to control weed species of economic importance in Alaska, where weed management is complicated by the wide range of ecosystems (temperate rainforest to Arctic tundra). The proportion of alien species in the Alaska flora (10.5%) is considered low compared to other regions (Rejmánek and Randall, 1994), suggesting that preventive measures, rather than herbicide management, are the best way to manage invasive weeds in Alaska. However, native or common garden weeds still pose significant challenges for growers. Preventive measures may be more feasible in Alaska than in other states because there are relatively few entry points for goods and people to enter the state. Identifying weed pathways into the state is probably the most efficient way to prevent future invasions. For example, straw and hay are used in Alaska for feed and bedding for domestic animals, erosion control, and storm-water pollution prevention, but contaminated hay has been associated with the introduction of invasive weeds into Alaska (Conn et al., 2008). The use of certified weed-free programs would help to reduce the spread of invasive weeds in Alaska, but only 1% of Alaska's straw and hay growers are enrolled in the program (Conn et al., 2010).

Use of herbicides to control weeds in Alaska is complicated by the high cost of shipping, the paucity of herbicides labeled for Alaska, some social opposition, and the possibility of herbicide injury to crops due to influences of cold soils and the short growing season. Non-chemical techniques are available to manage herbicide residues in the soil. For instance, mechanical dilution through moldboard plowing prior to planting could reduce crop injury resulting from metribuzin carryover from past seasons (Sharratt and Knight, 2005).

The use of plastic mulch coupled with drip irrigation is recognized as an effective practice to manage weeds in the lower 48 states. In addition to controlling weeds, plastic mulch preserves soil humidity and adds heat units to the soil. However, some growers in Alaska indicated that the shipping cost of plastic mulch is a deterrent to its use in the state. An additional consideration for use of plastic mulching as a sustainable practice is management of the waste plastic at the end of the season.

As discussed earlier, high tunnels can lower disease incidence and insect pest populations. However, they can result in earlier development of aphid infestations since aphids would prefer the warmer environment provided by high tunnels. Ladybeetles and biologically produced insecticides are available for aphid control inside these structures. The economics and effectiveness of insect control in high tunnels has not been scientifically studied in Alaska, but could share some similarities with those of greenhouse production.

The Cooperative Extension Service recommends five basic ways to control plant disease: exclusion, avoidance, eradication, protection, and resistance (Rader, 2011). When necessary, plant diseases are controlled by the appropriate chemical means. However, sustainable practices can limit disease occurrence in the first place. These include crop rotation, choosing sites appropriate for the crop (e.g., sunny vs. shade), using disease-free seed and transplants, maintaining appropriate levels of soil fertility, spacing plants appropriately, maintaining adequate water levels, controlling targeted insect pests quickly since they can be vectors for disease, removing diseased plants when they are seen, and ridding compost of disease by ensuring it heats up (Rader, 2011). However, many would advocate not adding diseased material to the compost pile in the first place.

Although sustainable management practices (mechanical, biological, and legislative control) are available and known for Alaska, additional research is needed to better understand the economics and feasibility, especially considering the geographic distance from main agricultural markets and shipping costs. More aggressive legislative measures could be required to prevent entry of invasive pests into the state. Prevention measures are more likely to be cost-effective than chemical control. Furthermore, breeding programs or the availability of pest-resistant varieties adapted to the long days and the short growing season could improve production in Alaska.

Development of Alaska's Livestock Industry

A small presence of traditional livestock exists in Alaska on small farms, ranches, and residences. When provided with basic shelter from rain and wind in summer and an escape from extreme cold in winter, traditional livestock can do well. The wide variety of livestock species raised in Alaska includes alpacas, beef cattle, bison, elk, sheep, goats, muskoxen, pigs, and poultry (ADNR, 2010a). The cash receipts from all livestock products in Alaska in 2011 totaled \$6.754 million (USDA NASS, 2012). Organically raised livestock and dairy have all been produced successfully in Alaska, and the resulting manure can be important for organic vegetable farming. Limitations to the growth of livestock production in Alaska are the expense of feeding and keeping livestock during cold winters, the cost of year-round labor, and the lack of suitable infrastructure. Farmers already producing grain or vegetable crops can integrate swine, chicken, or goats into their farms to generate additional income and produce manure for use as an organic fertilizer. Some residents already raise goats and northern sheep breeds on predominantly native forage, including shrubs (Paragi et al., 2010). Some benefits, costs, and drawbacks of raising goats, pork, or other non-indigenous livestock in Alaska have previously been reviewed (e.g., UAF CES, 2011a; Hecimovich and Shipka, 2012). Barriers to a sustainable livestock industry in Alaska exist in all stages of the process, from production to consumption (Helfferich, 2012b).

Since the mid-20th century, Alaskan reindeer herding has been highly localized and restricted to the Seward Peninsula and a few locations around Western Alaska. Alaska Native-owned reindeer are the basis of free-ranging livestock operations existing on the Seward Peninsula, St. Lawrence Island, Nunivak Island, and the Aleutian Islands. Island locations have proven to be especially effective for loose herding management because of their natural geographical barriers and lack of predators (Humphries, 2007). Fencing and supplemental feeding have been used to help manage reindeer in other areas (Finstad, 2007). A major limitation to reindeer profitability and a hindrance to meeting market demands is that regions with the large and remote ranges required for herding have often lacked adequate infrastructure for the slaughter, processing, and transportation of meat. However, the implementation of mobile slaughter and processing units through private and publicly funded pilot programs is greatly improving this aspect of reindeer herding.

The expansion of reindeer herding enterprises in Alaska was first demonstrated in the 1920s with many successful private operations. These operations faltered, however, following the Great Depression and disrupted market conditions (Shortridge, 1976; Stevenson et al., 2014a). The Reindeer Industry Act of 1937 (25 U.S.C. § 500 – 500n), in the hope of promoting economic development among Alaska Natives, prohibited non-Native Alaskans from owning Alaskan reindeer. Some non-Native Alaskans do legally raise reindeer that were brought in from Canada (Tarnai, 2010), but the resulting increase in the percentage of Alaska-grown red meat is minuscule. Historic herding numbers of Alaskan reindeer, particularly from the first half of the 20th century, suggest that a much larger percentage of Alaska's red meat demand could be met with in-state production. However, expansion of the industry to more parts of the state and to include more diverse ownership could create new socioeconomic and management challenges. While the concept of expansion to new areas is intriguing, it may require a reexamination of the Reindeer Industry Act, as well as informed dialogue about its feasibility and practicability and the benefits and drawbacks for stakeholders.

Improving Year-Round Local Food Supply

Alaska's year-round food supply is tied to regular barge and air transport of food from producers in the lower 48 states. More than 30 years ago, Dearborn (1979) speculated that by using some simple and ingenious agricultural management practices in combination with appropriate storage techniques, the Northwest Arctic region of Alaska could generate a sufficient food supply to help provide for itself year-round. Soon after, the Matanuska-Susitna Borough reported that several growers had invested in vacuum cooling and storage systems that quick-chilled produce immediately after harvest (MSB, 1983). This enabled them to be more flexible and extend the season by almost three weeks, while at the same time widening the farmers' marketing field. The extended shelf-life capability made it possible for the vegetables to be shipped anywhere in the state (MSB, 1983) and also helped to strengthen year-round food supply with locally grown foods.

The storage of food reserves, especially in rural and semi-rural areas, can be achieved in part through the use of root cellars, and this topic has received some previous attention (Roberts, 2000; Kaspari, 2013). Cold winter temperatures and soils provide ideal conditions for storing vegetables to maintain their quality. Outdoor root cellars must be deep enough so that vegetables can be stored below the frost line. Frost has been found to extend to 1.2 m below the surface (Kaspari, 2013) and to more than 3 m below the surface in parts of Interior Alaska (Sharratt, 1993). Late-maturing varieties that grow well into fall are recommended for winter storage.

Slowing down the respiration of produce using cold temperature helps to maintain its quality. The nutritional quality is highest when produce is freshly harvested. However, storage of excess fruits and vegetables in a manner that can maximize nutritional quality and provide an energy source year-round is ideal for a more sustainable approach in Arctic and Subarctic regions.

In some cases, it is highly desirable to have multiple storage facilities that would accommodate seed potatoes from harvest to planting, as well as stored foods (Dearborn, 1979). Summer vegetables have been kept in natural cold storage in places where permafrost is found by digging down to reach it. This method is similar to the traditional way that Native Alaskans stored caribou or moose meats, placing them in a naturally refrigerated subterranean meat locker approximately 2 m below the soil surface (Cochran and Geller, 2002; Brubaker et al., 2011).

Alaskan stakeholders (WSARE, 2010), the Alaska Food Policy Council (AFPC, 2012), and even the Alaska State Legislature (2013) have identified safe food processing facilities and safe food storage as top priorities for Alaska. Although home, community, or commercial cellars are simple to construct and require minimal heat in the coldest part of winter (a 100-watt light bulb near the floor may be sufficient), they are not particularly widespread. In a survey, the lack of cold storage was also cited by Fairbanks vegetable and fruit growers as one of the top 10 reasons for not expanding their farm (Caster, 2011). The current storage capacity in Alaska is unknown, but is widely thought to be too low in the event of an emergency situation and too low for the needs of Alaskan producers and even home gardeners.

SOCIAL AND POLICY SOLUTIONS

Agricultural development in the past century has focused almost solely on increasing production. However, advancing sustainable agriculture in Alaska and the circumpolar North must consider ecological and socioeconomic implications in addition to larger yields (Altieri, 1995). Social and policy solutions vary in their scope and complexity, but typically are the result of integrative efforts or cooperative strategies by stakeholders, legislators, working groups, and state or federal agencies.

Conservation and Affordability of Agricultural Lands

According to the Alaska Farmland Trust (2013), only 4% of Alaska's farmland is potentially available and suitable for farming. As of 2007, there were 356 765 hectares (881 585 acres) of farmland in Alaska, about 0.2% of the state's total area of 151 880 010 hectares (375 303 680 acres) (USDA ERS, 2007a); by comparison, Iowa has 86% of its total acreage in farmland (USDA ERS, 2007b). The purchase of farmland and operation of a profitable farm is challenging in many areas of Alaska. Conversion of farmlands to other land uses, especially urban and industrial uses, has been the largest, single threat to farmland loss in the United States. Private non-profit groups such as Greatland Trust and the Alaska Farmland Trust have purchased easements in Alaska on productive farmland in order to maintain continued farmland use.

Across the nation, farmland protection is overseen by the local government unit and may range from minimizing or mitigating impacts through the permitting process to full protection by ordinances and codes (Farmlands of Statewide Importance are agronomically productive or potentially productive lands designated and protected by individual states). The State of Alaska does not recognize "soils of statewide importance" and has deferred any important farmland designations to the local Soil and Water Conservation Districts. Lands identified by Soil and Water Conservation Districts, Boroughs, or Municipalities are Farmlands of Local Importance. In Alaska, the Soil and Water Conservation Districts propose criteria, the USDA-NRCS State Conservationist approves, and NRCS maintains a public record inventory of soils that qualify.

Protection of Farmlands of Local Importance in Alaska is limited to mitigation and minimization of impacts during project permitting. This strategy is only marginally successful since there is no statutory authority in the land designations. A designation of Farmlands of Statewide Importance and ordinance by the State of Alaska could provide an improved method of protecting the agricultural resource.

Protection of farmland through proven private and government-sponsored easement programs and the development of similar innovative ideas will help slow the trend of farmland conversion. Increased public awareness of the seriousness and high probability of food shortages associated with the reliance on a distant food source is also a key factor. Development of the agriculture industry also means improving infrastructure and making farm equipment more available to more people at a reasonable cost.

Advancing Markets and Marketing Strategies

When local farms market and sell directly to consumers, both parties benefit. The consumer knows that the produce is fresh and was grown in the state, and the farmer can set a fair price without having to give a cut of profits to a retail store or distributor. Even in rural areas, farmers are using e-mail and online services more than ever before to market their products, notify potential consumers, and coordinate farmers' market opportunities. "Eat local" initiatives such as farm-to-table campaigns, "U-pick" markets, and "Alaska grown" advertising have had positive results, and online social media outlets also provide easy, inexpensive, and efficient methods for farmers to network, connect, and market to consumers. The Alaska Grown ad campaign, a promotional tool developed by the Alaska Division of Agriculture to advance local agriculture, has prompted feature displays in Alaska grocery stores and other markets (Fig. 4).

Popular direct marketing strategies include farmers' markets, community shared agriculture, and U-pick farms. Farmers' markets are venues where several farmers sell produce, usually one or more times a week. Community Shared Agriculture (CSA) means that consumers purchase a share of the farmer's produce at the beginning of the season and then pick up their share each week. A U-pick farm allows consumers to come directly to a farm to harvest produce, usually at a reduced price. Alaska currently has about 35 farmers' markets, 39 CSAs, and five U-pick farms (ADNR, 2010b; USDA, 2011; Helfferich, 2012a). A recent USDA news release noted Alaska's rising interest in local foods, documenting the astonishing growth of farmers' markets in the state. Between 2010 and 2011, Alaska showed a 46% increase in farmer's markets—the fastest rate of growth among all the states and far above the national average of 17% growth during this time (USDA, 2011). Helfferich (2012a) reported a two-thirds increase in the number of CSAs in just 18 months from June 2010 to January 2012. Buying local products is thought to keep money in local communities longer—generating perhaps twice as much income for a local economy. In contrast, money leaves the community with every transaction when businesses are not locally owned.

In addition to direct marketing, stores that are open year-round and feature Alaska products could be an important outlet for farmers. Stores that give priority to locally grown produce include the Fairbanks Community Cooperative Market (opened in 2013) and the Alaska Homegrown Market (opened in 2010). Some farmers sell through corporate grocery chains, but farmers' profit margins are often too slim or retailers too inflexible for small farmers. Cooperatives centered on a particular crop or group of crops are

FIG. 4. An Alaska Grown display featuring local products in the entrance to an Anchorage supermarket, August 2013. (Photo: Kalb Stevenson.)

being formed in Alaska and gaining momentum for very specific products, such as peonies for their decorative floral appeal or *Rhodiola rosea* as an herbal health supplement. Cooperatives have the potential advantages of providing producers with higher profit margins, more influence on the retail price, and assistance with marketing, while releasing them from time-intensive direct marketing outlets.

To address Alaska's market challenges, it is helpful to understand why residents, especially those in more densely populated urban or semi-urban communities, might do their food shopping at one-stop supermarkets and warehouse stores rather than at farmers' markets or other small, local stores. Acquiring local foods at farmers' markets or small stores such as co-ops is not as convenient as shopping at mega-stores, and such outlets do not operate year-round. Farmers' markets are often weekly, weekend-only occurrences, and typically operate only in summer, although there is a year-round market in Anchorage (The Center Market). Corporate supermarkets and warehouse stores that sell imported foods in greater quantities and in more diverse varieties also provide a consistent, year-round supply of diverse foods. By some people's standards, these stores also provide a more comfortable and more aesthetically pleasing shopping experience that includes the concurrent sale of non-food items. Add to this the fact that the imported foods sold in grocery stores are often cheaper, and this becomes a "no-win" situation for local products.

The matter of product choices is another challenge that will require some serious thought to generate some realistic solutions. Alaskans grow non-glamorous "foundation" foods, such as potatoes, carrots, and cabbage in the largest quantities. Societies obtain very few of their calories from these foundation foods, and they take longer to prepare than out-of-the box foods. Fewer people truly cook from scratch today, as compared to previous decades. Alaska has almost no food processing capability in the state, so agrarian-minded Alaskans must work to find ways to provide more diverse foods that will be marketable to residents. Additionally, a growing number of Alaskans identify strongly with their local foodshed and are concerned about a lack of food security (Helfferich and Tarnai, 2010). This trend could be an important shift in support away from a corporate-based food system to a locally based foodshed (Kloppenburg et al., 1996).

Integrative and Cooperative Solutions

Solutions to Alaska's agricultural challenges are rooted in cooperative efforts and involve local and regional stakeholders. Kloppenburg et al. (2000) and Tregear (2011) emphasized the importance of involving farmers and consumers when developing food system models. How is Alaska moving from beyond the limits of its technical field-based solutions and largely theoretical administrative notions to a place where its agriculture can improve and thrive? A first step is acknowledging the need for greater stakeholder involvement and an avenue of communication with state and federal agencies on the issues pertaining to food security. This step has begun with cooperative interaction in working groups of the Alaska Food Policy Council (AFPC), a growing body of hundreds of stakeholders in Alaska who advocate improved access to healthy, affordable, and culturally appropriate foods for residents of the state.

The AFPC has summarized Alaska's food systems and the cycle of food in the state (presented in Helfferich, 2012a) and set five goals for strengthening and advancing agriculture in the state (AFPC, 2012:8 – 11):

- All Alaskans have access to affordable, healthy (preferably local) foods.
- Alaska's food-related industries have a strong workforce and operate in a supportive business environment.
- Food is safe, protected and supplies are secure throughout Alaska.
- Alaska's food system is more sustainable.
- Alaskans are engaged in our food system.

The AFPC (2012:7) also identified five strategies for 2012–15:

- Develop, strengthen and expand the school-based programs and policies that educate about and provide healthy, local foods to schools (e.g., Farm to School Program, Agriculture in the Classroom, traditional foods in schools, school gardens)
- Strengthen enforcement language in the Local Agricultural and Fisheries Products Preference Statute (AS 36.15.050), also known as the "Seven Percent" statute and Procurement Preference for State Agricultural and Fisheries Products (Sec. 29.71.040)
- Advocate and participate in the development of community level and comprehensive statewide emergency food preparedness plan(s)
- Develop AFPC's role as research aggregator and resource
- Identify and support existing local food system leaders,

projects, events, and activities that support Alaska's food system.

These goals and strategies are the result of cooperative efforts among stakeholders and leadership towards greater agricultural independence for the state.

In 2013, the Alaska State Legislature passed House Concurrent Resolution 1 (HCR1), which requested that the governor create a state food resource development working group to advise the legislature on food policy issues and bring together various stakeholders to local food markets and increase Alaska's food security (Alaska State Legislature, 2013). The legislation outlined an ideal scenario for collaboration between stakeholders, policy makers, and agencies that would help Alaska to move forward toward solving many of its food security issues. HCR1 recognized the need for Alaska to increase both the local production of food and the consumption of local wild seafood and farm products in order to improve the health of residents of the state, increase food security, strengthen the local economy, and encourage community development.

Under HCR1, the state food resource development-working group was directed to identify new or expanded economic opportunities for residents of the state in new food production, food processing, and food distribution businesses. It was directed to work alongside and in collaboration with (a) the AFPC, to identify resources and set policies to build a strong and sustainable healthy food system in the state; (b) nonprofit organizations and local food banks, to develop and use the state's food resources; (c) the USDA, to develop programs that encourage the growth and use of the state's food resources; and (d) Alaska Native regional corporations, to preserve, enhance, and expand the traditional uses of the state's food resources and encourage the development of locally produced food resources in the corporations' regional communities.

The resolution further requested that Alaska's state agencies participate actively as collaborators with the state food resource development working group by reviewing existing or proposed programs, policies, and regulations that affect the state's food system. The agencies' role would be to recommend to policy makers ways to improve the coordination and implementation of the programs, policies, and regulations. The agencies would also collaborate with the established state food resource development working group and the AFPC to enhance the access, availability, affordability, and quality of food for residents of the state. The roles of different state agencies and entities in this process are shown in Table 2.

The Alaska Food Policy Council, growers, government officials, researchers and Extension agents must work together to develop and take advantage of solutions to market challenges. If Alaska possessed stronger, more profitable markets for local growers, it is probable that producers would find a way to overcome several other obstacles, thereby drawing the agriculture industry into a state of greater maturity.

Changes to Federal Funding for Sustainable Agriculture in Alaska

Gardening and farming are gaining in popularity in Alaska's more remote cities, towns and villages. Lempinen (2008) noted that community gardens have been started in cities and towns from Juneau on the Panhandle, to Bethel in the interior southwest, to Fort Yukon on the Arctic Circle. Nearly two dozen communities now have farmers' markets, with Sitka being among the latest. This growing interest is due in part to the longer growing season brought about by changing weather patterns, as well as to advances in marketing and increased use of online social media.

While Alaska is arguably the most rural state, there are few rural agrarian areas, in part because subsistence fishing and hunting are emphasized in most communities. Furthermore, people who may want to start farming or ranching for the first time often cannot access government programs. To be eligible for many USDA programs, one must already be a farmer or rancher, or someone who sells or is capable of selling at least $1000 worth of agricultural products in a given year. Yet it is beginning farmers who often need the most help. Although some federal loans or funds are set aside for Alaska Natives or American Indians through the Socially Disadvantaged Farmers or Ranchers program, currently there are only 28 American Indian or Alaska Native farmers and ranchers (USDA NASS, 2012).

The USDA commodity program is another example of a large program that is virtually inaccessible to Alaskans. According to the 2007 Census of Agriculture, the majority (86% to 91%) of corn, sorghum, soybean, and wheat farms together received more than 10 million U.S. dollars in government payments that year (USDA, 2009b). For instance, a total of 299 243 corn farmers received an average of $13 305 each in government payments, while making an average of $16 395 in farm income. The amount of government payments received by an average sorghum farmer exceeded that of his or her average farm-related income. These crops require relatively warmer growing conditions than are available in Alaska for consistent and economical production. Unfortunately, there is no federal support for the nursery and greenhouse industry, which is the second-largest agriculture industry in Alaska (USDA, 2009a) and in the U.S. (USDA, 2009c).

In 2010, the Western Sustainable Agriculture Research and Education program, funded by the USDA, facilitated a strategic planning conference for Alaska to identify barriers to sustainable agriculture in Alaska and ways to overcome them. The conference participants included almost 120 farmers, ranchers, agriculture professionals, and others (WSARE, 2010). This process served Alaskans well because it gave Alaskan growers a chance to voice their issues and needs for sustainable agriculture in Alaska and to offer solutions relevant to many USDA grants and programs. It gave an opportunity for all parties to discuss the development of place-based solutions and the support needed to influence policy. A new USDA program, the Beginning Farmer and Rancher Development Program

TABLE 2. Roles of Alaska state agencies and entities in collaboration with the Alaska Food Policy Council and the state food resource development working group, as proposed in Resolution HCRI (2013) of the Alaska State Legislature.

Alaska State agencies and entities	Proposed role
Department of Commerce, Community, and Economic Development	Develop marketing and promotional programs to identify new and expanded opportunities for residents of the state in food production, food processing, and food distribution businesses
Department of Corrections	Develop a program to use state food sources as part of the Department of Corrections' institutional food service programs
Department of Education and Early Development	Work with the state food resource development working group to develop nutrition programs that include locally produced food in school meals and education programs that highlight state food sources and work with the National Future Farmers of America organization, the National 4H Council, the Alaska Farm Bureau, the National Grange of the Order of Patrons of Husbandry, and other farming groups to foster future generations of farmers in the state
Department of Environmental Conservation	Develop a working group to enhance the health, safety, welfare, and overall economic and social well-being of residents of the state by instituting programs and adopting regulations that encourage the development of the state's food resources
Department of Fish and Game	Work toward protecting, preserving, and managing fish and game harvests in the state
Department of Health and Social Services	Develop strategies and educational programs to inform Alaska residents about the nutritional value of locally harvested seafood and produce
Department of Military and Veterans' Affairs, Division of Homeland Security & Emergency Management	Develop a method to use state food sources as part of the governor's disaster and emergency preparedness food supply program
Department of Natural Resources, Division of Agriculture	Promote and encourage development of an agriculture industry in the state
Multi-Agency: Department of Health and Social Services, Department of Education and Early Development, Department of Corrections.	Work with the state food resource development working group to improve the health of state residents by developing nutrition policy standards for congregate meal programs in public facilities
University of Alaska, School of Natural Resources and Extension	Research and develop a sustainable supply of locally produced food and extend knowledge of a sustainable agriculture system

(authorized in 2008), does show promise of meeting the nascent needs of Alaskan growers. One project funded in 2010, the Alaskan Growers School, celebrates a traditional subsistence lifestyle while offering the knowledge and skills to successfully pursue sustainable agriculture opportunities in the state. If the USDA could allocate money to regions or states, rather than through national programs, it could be more responsive to local needs and issues.

A Better Food Security Index?

One solution to the problem of food insecurity not discussed in the paper is the development of a food security index for Alaskan communities. Although alternative food networks have been well researched in recent years, inherent issues with much of this research have been noted, including lack of data or inconsistencies in data (Tregear, 2011). In Alaska, food system research is relatively new. An extensive report on Alaska's food system recently prepared by Hanna et al. (2012) is perhaps the first of its kind. Unlike Maxwell's (1996) focus on household food insecurity, or Barrett's (2010) focus on global food insecurity, a more salient focus for Alaska would be at the community level. A food security index similar to the Arctic Water Resources Vulnerability Index (Alessa et al., 2008) could integrate environmental, physical, and socioeconomic data from specific locations to determine a community's level of vulnerability or resilience. It would integrate data on climate, soils, farms, markets, farming costs, subsistence use, food imports, and distance from major food and supply centers to diagnose food-related issues for individual communities. The index could be organized around Barrett's (2010) pillars of food insecurity: availability, access, and utilization. This index could then support the initiation of new policy to begin correcting the problems faced at different levels throughout the state. As Barrett (2010:827) notes, "measurement drives diagnosis and response" or at least it has the potential to do so as part of the integrative and cooperative solutions discussed above.

Documenting and Publicizing Success

Since 2009, the stories of more than 60 Alaskan farmers and ranchers have been documented and published as individual profiles in local newspapers (Tarnai, 2012a). These profiles promote sustainability in local agriculture by disseminating information in an engaging format to members of the local communities. For instance, one farmer uses Manley hot springs to heat a greenhouse where he grows a variety of warm season crops and then transports them to Fairbanks (Tarnai, 2011a). A different farm uses online ordering to provide an à la carte CSA so that members can customize their share of produce each week (Tarnai, 2012b). Farmer Jen Becker overcame the challenge of securing agricultural land through tenant farming (Tarnai, 2011b), while rancher George Aguiar raises livestock for meat and for agritourism (Tarnai, 2010). Through these stories, the innovative models and niches of these farmers are often shared with other agricultural professionals and consumers in a way that documents success while engaging and informing the public.

Since 1969, the journal *Agroborealis* has been one of the primary means for the Agriculture Experiment Station at the University of Alaska Fairbanks to share research as well as lessons learned from Alaskan farmers. With Experiment Stations limited to Fairbanks and Palmer, the importance of the experience and knowledge of Alaskan farmers cannot be overstated. *Agroborealis* has shared important information on emerging crops such as peonies and *Rhodiola*, food security, direct marketing, and reindeer in Alaska.

SYNTHESIS AND CONCLUSIONS

Growers in Alaska and around the circumpolar North have implemented technical field-based solutions and social and policy solutions to meet many of the challenges to sustainable agriculture (Fig. 1). Technical field-based solutions involve using specialized infrastructure or modified field management techniques to extend the growing season, improve soil quality and nutrient content, or improve irrigation systems and watering practices. Social and policy solutions are resolutions stemming from decisions made by community members, organizations, agencies or legislators. These solutions address issues through funding of research, education, and infrastructure for local agriculture; the expansion of marketing and social media solutions; improved markets; and new policies to address high costs of land or availability of agricultural lands to private businesses. Administrative solutions also include integrated and cooperative efforts between Alaskan stakeholders (e.g., the Alaska Food Policy Council), state and federal agencies, and other entities. Collectively, these solutions will help to define the coming of age of sustainable agriculture in Alaska.

Food security in Alaska cannot be obtained exclusively through local agriculture in its current form, nor can it exist with the state's current level of dependency upon imported foods. Correcting Alaska's food insecurity issues means revising policies at the state and federal levels so that through a cooperative partnership, stakeholders and government can develop a multi-faceted and cooperative approach that will most benefit Alaskans. It means understanding the field-based challenges and solutions, but also being able to move beyond them into practical application.

Ideally, Alaska's food security should eventually progress so that it will meet the following benchmarks:

First, food security must result from improvements in local agriculture that provide (a) greater opportunity for existing and prospective growers to develop profitable businesses, expand farms, and integrate proven techniques; (b) greater availability to private growers of affordable lands suitable for agriculture: and (c) an improved market for local foods.

Second, it will mean working to reduce dependence on imports by not importing foods that are already produced locally. As community members, organizations, and lawmakers work to improve local markets and increase the consumption of local foods, the proportion of imported food in the diet should decrease.

Third, Alaska must recognize the need to continue integrating wild foods traditionally harvested in the state (fish, game, and other resources) into the discussion of Alaska's overall food security. Agriculture alone cannot provide food security: there are challenges that simply cannot be overcome. But Alaskans should remember that the earliest Native and white settlements lived sustainably for centuries without any local agriculture or food imports.

Fourth, Alaskan growers should affirm the need for place-based decisions regarding technical, social, and policy solutions. Alaska is huge and diverse, and no "one-size-fits-all" solution will work everywhere in the state, or in the entire North. The solutions presented in this paper will vary in efficacy from place to place, and some are more critical in one locality than in another.

Finally, Alaskan stakeholders should consider integrative solutions at the state and federal levels. If a state food resource development working group is successful in working cooperatively with stakeholders (e.g, via the AFPC) and agencies, and if changes to federal programs and granting opportunities can better take into account the challenges faced by Alaskans across their expansive and diverse land, Alaska will have made progress toward dissolving its food insecurity and achieved greater sustainability.

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