An Investigation into Ecological Farming Systems on the Canadian Prairies

by

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ABSTRACT

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There are currently numerous alternative food production models that may have potential to contribute substantially to improved environmental sustainability. However, such alternatives are not well studied, particularly within the context of the Canadian Prairies. To increase knowledge in this area, this thesis performed a preliminary agronomic trial for food grain production in intermediate wheatgrass (*Thinopyrum intermedium*), investigating the effects of legume intercropping and residue management. Mean grain yields were 520 and 447 kg/ha in 2014 and 2015, respectively, and a significant yield increase was observed following grazing with sheep. A series of farm case studies were also conducted in order to characterize ecological farming approaches on the Canadian prairies. The most consistent strategy among the farms was to increase diversity in multiple facets for both environmental and economic benefit, including more crop and livestock species, system and landscape components, and marketing strategies.

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1. INTRODUCTION

Global food production faces unprecedented challenges in the coming decades and is very likely to be profoundly altered by a rapidly changing world. Some of these challenges are an increasing population and food demand (Sakschewski et al. 2014), continued soil erosion (Montgomery 2007), pesticide resistant insects, weeds and disease (Tilman et al. 2002), maintaining water quality (Schindler et al. 2012) and quantity (Famiglietti 2014), biodiversity loss (Chappell and LaValle 2011), and unprecedented reductions in pollinator populations (Potts et al. 2010). Perhaps more important still is climate change which has the potential to significantly reduce global food production through drought, heat waves, extreme environmental events, and increased disease and pest occurrence (Porter et al. 2014).

Considerable effort has already been made to address these issues within agricultural research, and powerful new technologies such as biotechnology and genetically modified organisms (Wolfenbarger and Phifer 2000), precision agriculture (Hedley 2015), and most recently "big data" (Bronson and Knezevic 2016) have been and continue to be developed for that purpose. While such approaches are extremely effective in increasing productive agricultural output, they are employed to homogenize and control what are still largely natural systems ever more tightly. The continued emergence of new crop diseases and herbicide resistant weeds as a result of the predominant agricultural system requires continued investment in these technologies in order to maintain control (Tilman et al. 2002; Papaïx et al. 2015). However, as level of control increases, farmers operating within this model become increasingly dependent on its continued functioning for their success - both in terms of extraneous inputs and in terms of knowledge (Gliessman 2007). Moving in such a direction has been criticized as making it increasingly difficult for small farmers to make a living and increasing dependency on foreign governments and corporations that may not act in the best interests of the people, particularly within developing nations (Altieri 1989; Gliessman 2012).

It is possible to address many of these issues by understanding natural and ecological processes and applying them within agricultural contexts, otherwise known as agroecology (Gliessman 2007). Such strategies are often associated with increasing management complexity and lower productive output (Giampietro 2004), but can result in profound social and environmental benefits (Kassam et al. 2009; Reganold and Wachter 2016). Technological solutions can also sometimes allow for the application of concepts that are not available under other circumstances, such as the mulching and reduced tillage enabled by herbicide tolerant crops of Conservation Agriculture (Palm et al. 2014).

However, agroecological understanding remains fragmented across disciplines to some degree, and is not widely discussed within the wider culture of North America (Ferguson and Lovell 2014). Ecologically oriented approaches to food production are instead generally conceived as discrete strategies and, as in the case of Holistic Grazing Management (HM) and Permaculture, have not always received extensive attention from the research community. Because solving agricultural problems using agroecological approaches offers a great deal of promise in enhancing the environmental sustainability of food production, developing a more generalized understanding of how agroecology can be applied in different contexts may be valuable in maximizing its benefits.

This thesis consists of two distinct chapters that explore innovative application of agroecology on the Canadian Prairies.

The first chapter looks at perennial grain crops, a nascent agricultural technology that has the potential to result in a new agroecological paradigm. Perennial grain systems have the potential to solve or greatly reduce the problems of annual production by allowing the advancement of plant ecological succession (Cox et al. 2006; Crews et al. 2016), and have been suggested as a solution to "the problem of agriculture" (Jackson 1980). Domestication of intermediate wheatgrass [*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey] (IWG) is underway at the University of Manitoba, using seeds bred at the Land Institute, KS (DeHaan et al. 2013), but little agronomic research has been done on the field-scale production of this perennial crop. The objective of this project was to establish a baseline yield for IWG grown under organic conditions, and compare the effects of intercropping different legume species and different residue management strategies including crop-livestock integration on grain yield and biomass production. Both legume and livestock integration have been suggested as strategies to enhance the environmental and economic viability of this system (Wagoner 1990; Bell et al. 2008; Crews et al. 2016).

The second chapter is an observational study, consisting of a series of case studies on ecologically-oriented farm systems on the Prairies of Western Canada. The objective of this study was, broadly, to answer the question " what does ecological farming look like on the Canadian Prairies?" with the purpose of gathering a wide range of ecologically driven practices and farming models that have not been well studied in this region to date. The case studies were contextualized by gathering information beyond the bio-physical characteristics of the farms, allowing for better understanding of the social and economic dimensions of these innovative systems. This approach was taken in part to address calls for greater holistic understanding and planning at the farm level and to incorporate the social dimensions of farming, whose importance is increasingly recognized (Phelan 2009; Wezel et al. 2009).

2. LITERATURE REVIEW

2.1 Perennial Grain Overview

2.1.1 Background

While global agriculture has always been dominated by annual crop production, certain cultures have sometimes relied on perennial species such as wildrye (*Leymus* spp.) for the Vikings of Greenland and Iceland, or biennials like *Bromus mango* Desv. (*mango*) grown in Chile (Wagoner 1990). During the 20th century, Soviet researchers spent a number of years working towards producing perennial grains, mostly crossing annual wheat (*Triticum*) with wheatgrass (*Thinopyrum*) or wildrye (*Leymus*) species but also perennial rye between 1930 and 1970 (Wagoner 1990). However, sterility problems and the fact that viable hybrids were very weakly perennial at best (and yields decreased considerably in the second year) resulted in the ultimate abandonment of those projects (Wagoner 1990; Hayes et al. 2012).

The contemporary, Western interest in developing perennial grain crops is largely due to the vision of Wes Jackson, presented in *New Roots for Agriculture* (Jackson 1980). Here Jackson detailed the problems of and attempted solutions for agriculture in early 20th century America, including soil erosion, environmental degradation, farm policy, and the financial difficulties of farming. He argued that it was necessary to have a different conception of the role of the farm and that a sustainable and equitable society would require the development of polyculture-based agricultural systems centred around grain production. The ultimate goal is to mimic the prairie ecosystem in order to solve "the problem of agriculture" (Jackson 2002).

2.1.2 Advantages

Farming with perennial grain crops is expected to have a positive influence on a wide range of environmental and economic attributes compared to annual production. The main features of perennials that contribute to these benefits are their increased lifespan and their larger root systems (Cox et al. 2006; Pimentel et al. 2012) as well as their potential to be grown on more marginal land (Glover et al. 2010). Currently, IWG root systems grow to two to three times the depth of annual wheat and maintain much of that size throughout the year (Cox et al. 2006). Although there is some anticipation that these attributes may be reduced somewhat through domestication or hybridization given (for example) the negative correlation of longevity and yield (DeHaan et al. 2005; Vico et al. 2016), they still have profound ramifications for agricultural sustainability.

Perhaps the most important advantages of perennial crops derive from reduced cultivation of the soil. Reduced physical disturbance (tillage) inherently improves a wide range of parameters, including soil aggregate stability, microbial diversity, carbon balance, and erosion (Culman et al. 2010; Paul et al. 2013; Palm et al. 2014). Erosion is further controlled by having living crop cover at all points of the entire growing season, which also enhances water infiltration (Glover et al. 2010). Root systems that push deeper into the soil profile contribute exudates and senesced tissue, providing energy and carbon that lead to a greater extent of biological activity (Cox et al. 2006; Crews et al. 2016). Even by maintaining perennial crops in production for a few years within rotation (Bell et al. 2008), research has shown that similar inclusion of perennial forage has had a dramatic positive impact in soil quality (Gentile et al. 2005; Acosta-Martinez et al. 2010). Interestingly, it is anticipated that as carbon accumulates towards a new equilibrium as soil organic matter (SOM), there will be an initial reduction in nitrogen availability given that the C:N ratio of SOM ranges between 10 and 15:1 (Crews et al. 2016). In Manitoba, research has shown that perennial cover in the form of restored grasslands resulted in higher levels of soil carbon compared to low input and forage including cropping systems (Bell et al. 2012). However, Bell's results suggest that differences may take many years to manifest and be strongly dependent on management system and soil texture.

Improved nutrient and water use is another huge potential advantage of perennial cropping systems, which are currently associated with significant economic and energetic costs (Smil 2002) and environmental externalities (De Vries et al. 2013) within the annual paradigm. Because perennial root systems grow much deeper into the soil profile, allowing for increased nutrient and water uptake while helping to lower leaching losses of both (especially nitrate) below the root zone (Crews 2005; Cox et al. 2006; Jerry Glover et al. 2010; Crews et al. 2016). This expectation is strongly supported by experimental evidence in Manitoba, where cover by both native grasses and alfalfa (*Medicago sativa*) resulted in significantly lower levels of nitrate at lower depths in the soil profile compared to an annual rotation, especially after 4 years (Entz et al. 2001). It is also expected that nutrients will be used more efficiently: perennial grasses have been shown to translocate nutrients from leaves to storage structures before senescing in the fall, again minimizing nutrient loss and contributing to early-season growth in the spring (Bausenwein et al. 2001).

Perennial crops are also anticipated to reduce energy inputs into agricultural systems, resulting in economic benefits for farmers. The main reason is lower fuel and machinery costs: perennial systems do not require tillage or seeding every year (Watt 1989; Bell et al. 2008). Furthermore, less fertilizer application (energy intensive both to produce and apply) is likely to be required in the longer term (Crews et al. 2016) and there is expectation that domesticated perennial crops will require less pesticide and fungicide (DeHaan et al. 2005; Cox et al. 2006). Nevertheless, perennial grain stands are likely to have unique challenges regarding pests and disease, which may be managed through genetic diversity or disturbance (e.g. burning or grazing) (Cox et al. 2005) or through the development of polycultures or intercrops (Pimentel et al. 2012).

2.1.3 Criticism

The feasibility of perennial grain development has recently been debated (Crews and Dehaan 2015; Smaje 2015). The heart of the argument against, also identified by DeHaan et al. (2005) and Cox et al. (2002), is that perennial plants necessarily allocate a smaller proportion of their energy towards reproduction than do annuals, and thus can never produce comparable yields on a per hectare basis (Smaje 2015). The argument is derived from the work of Philip Grime who categorized plants into ruderal, stress tolerant, or competitive life history strategies where energetic, ecological trade-offs are necessary to succeed under different conditions (Grime 2001): for example, ruderal (annual) species have a strong incentive to invest large amounts of their resources in maximizing their reproductive output while longer lived species put resources into more vegetative growth and secondary metabolites in order to compete and survive. This argument has been supported to some extent by Vico et al. (2016) who found that lifespan and root size were negatively correlated with seed yield, implying such a trade-off. However, Vico et al. (2016) stated that comparable yields might be achievable with a high degree of perennial biomass production.

Land Institute researchers question whether these trade-offs are absolute and argue that competitive perennial grain yields are indeed possible through breeding and management (Crews and DeHaan 2015) especially under favorable, human-mediated conditions (DeHaan et al. 2005). While DeHaan et al. (2005) acknowledge the existence of the pattern in nature identified by Vico et al. (2016), they point out that not all annual species in nature have a higher reproductive allocation than their perennial counterpart, using sunflower (*Helianthus* spp.) as an example. Furthermore, recent yield increases in annual crops have come through increasing stress tolerance and competitiveness (Crews and Dehaan 2015). Finally, clonally reproduced tree species sometimes have a reproductive allocation of over 50% - which is as good or better than most annual crop species (DeHaan et al. 2005; Van Tassel et al. 2010).

2.1.4 Strategies for Perennial Grain Crop Development

There are two paths towards producing productive perennial grain crops: wide hybridization of annual species with perennial relatives, and the new domestication of existing perennial species (Wagoner 1990; DeHaan et al. 2005; Cox et al. 2006; Cox et al. 2010). Most perennial grain development has focused on hybridization for a number of crops in several locations, including rice in China, maize in Texas, and wheat in a number of locations that include Italy and the Land Institute in Kansas (Batello et al. 2013). The hybridization approach was also employed by 20th century Russian breeders looking to perennialize wheat and rye (Wagoner 1990).

Domestication efforts have been the most longstanding at the Land Institute, where progress continues to be made on domesticating IWG, perennial sunflower (*Helianthus maximiliani* Schrad.), increasing the perenniality of sorghum (*Sorghum bicolour* (L.) Moench/S. halepense (L.) Pers.), and a new oilseed crop Silphium (*Silphium integrifolium*) which shows a great deal of promise (Cox et al. 2010; Van Tassel and DeHaan 2013). More recently, domestication work on IWG and perennial sunflower have begun at the University of Manitoba (DeHaan et al. 2013).

Focusing on perennial wheat and IWG, both approaches present their own advantages and challenges. Hybridization between annual wheat cultivars and wild perennial relatives (often IWG) has resulted in crosses that produce high yields but low perenniality or poorer yielding, longer lived progeny - the results caused by the relative proportions of genetic material from the parent plants (Hayes et al. 2012; Jaikumar et al. 2012). Another common problem has been plant sterility, where crosses are only rarely reproductively viable (Cox et al. 2002).

While it is theoretically possible to propagate high performing individuals via asexual methods, as is the case for high yielding woody perennial and tree species grown for fruit production, the small size of herbaceous grass plants makes such an approach unfeasible for broad acre grain production (Van Tassel et al. 2010).

In some ways, domestication is a longer and more complex process and the domestication of a new species has not occurred more recently than 1000 years ago (Meyer et al. 2012). Species selection is important to minimize the changes needed in order to make a candidate agronomically viable. When identifying IWG as the best candidate for domestication of a perennial wheat analogue, researchers at the Rodale Institute considered ten different attributes (Table 1) (Wagoner 1990).

Table 1. Traits used by the Rodale Institute for selection of candidate species for perennial grain domestication (after Wagoner 1990)

- perennial growth	- palatable flavor
- easy threshing	- large seed size
- resistance to shattering	- uniform seed maturity
- strong seed stalks	- seeds above foliage
- potential for mechanical harvest	- seed stalks dry at maturity

After selection, the breeding process involves succeeding rounds of selections relying on sexual reproduction. Major increases in seed yield for an IWG forage variety 'Ree' were made through rounds of mass selection in the 1970s (Knowles 1977) and ongoing development at the Land Institute has taken a similar approach (L. DeHaan et al. 2005; Cox et al. 2010). The main challenges to this process with IWG are that the species is currently almost entirely an obligate outcrosser (i.e. plants cannot produce viable offspring from self-pollination) (Dewey 1978; Asay and Knowles 1985) and that perennial species tend to acquire a genetic load of deleterious mutations over evolutionary time (DeHaan and Van Tassel 2014). DeHaan and Van Tassel (2014) describe these mutations as being generated vegetatively in long lived species like IWG and passed on through the seed, often having mild negative effects or being masked by more dominant alleles. In order to reduce the genetic load, the plants undergo a controlled reduction and management of diversity through inbreeding and lowering population size in order to break the association of certain genes with lower yield. Other strategies for accelerating domestication are fixing traits that are currently plastic in response to favorable (i.e. agriculturally relevant) growing conditions and heterosis, where progeny exhibit superior characteristics compared to their parents (DeHaan and Van Tassel 2014).

2.2 Intermediate Wheatgrass (*Thinopyrum intermedium*)

2.2.1 Background

After extensive testing of more than 100 species at the Rodale Institute, IWG was identified as the most promising candidate for the domestication of a perennial grass species for temperate grain production (Wagoner 1990).

IWG is a temperate, C_3 grass whose natural range extends from the Mediterranean through southern Russia, not being found below 30°N (Dewey 1978; Asay and Jensen 1996). It was originally introduced into North America in 1907, but did not see significant use until after 1932 with the release of the 'Ree' cultivar, a variety imported from the USSR (Asay and Knowles

1985). A number of varieties have since been developed, in part owing to its large trait and genetic diversity (Asay and Knowles 1985). As a member of the *Triticaceae* tribe it hybridizes readily with annual wheat (*Triticum aestivum*), which has given it an important role in early (Russian) and contemporary efforts to develop perennial wheat as well as improving traits like disease resistant in annual cultivars (Wagoner 1990; Cox et al. 2010; Tang et al. 2014). Currently in North America, it is most commonly used as a forage grass in the northwestern United States because of its high productivity and reasonable protein content (Lawrence et al. 1971; Hybner and Jacobs 2012).

IWG is characterized as a moderately rhizomatous, obligatory crosspollinated grass (Asay and Knowles 1985), although wild examples of self-pollinated plants have been found (Dewey 1978). Its root systems can grow to be quite extensive, reaching more than 3 m in length (Cox et al. 2006). Though it does not grow well under excess water or salt stress, its relatively large seeds and tall growth habit make it easy to establish and grow in conjunction with alfalfa (Asay and Knowles 1985). It is best adapted to areas with more than 350 mm annual rainfall, while crested wheatgrass (*Agropyron cristatum* (L.) Gartn.) or the subspecies pubescent wheatgrass (*Thinopyrum intermedium* subsp. *barbulatum*) perform better in drier environments (Asay and Jensen 1996). Although its requirements for floral induction have not been conclusively established, it is probable that vegetative tillers require dual induction through a period of cold temperatures followed by long day lengths before becoming reproductive (Heide 1994).

2.2.2 Seed and Biomass Production

Agronomic experiments looking at IWG for seed and biomass production are limited, limiting consensus on management practices. Both IWG seed and biomass yields vary widely between experiments, in addition to the pattern of seed yield decline after multiple years of cultivation. Experiments that report higher seed yields tend to also keep them consistently higher, averaging between approximately 450 and 550 kg/ha over 3 to 5 years (Canode 1964; Darwent et al. 1987). In contrast, Wagoner (1990) reported first year yields of 566 kg/ha that decreased to 156 kg/ha in year two, followed by further decreases which may have been similar to a Montana experiment where yields were 200-350 kg/ha averaged over 5 years (Black and Reitz 1969). Seed yield does not appear to be necessarily associated with biomass production, although inorganic fertilizer application appears to have a positive effect on both (Canode 1968; Darwent et al. 1987). Published biomass values range from 2000 to 5900 kg/ha (see Table 13, Section 3.4.1 Overall Yield), with the highest values associated with the lowest seed production (less than 250 kg/ha) (Lee et al. 2009). It should be noted however that the IWG stand for Lee et al. (2009) was already 4 years old at the beginning of their experiment.

Initial perennial grain trials at the Rodale Institute indicated that establishment following small grains was more successful than perennial legumes due to less weed pressure in a lower N environment (Wagoner 1990). Otherwise, seeding depth appears to be the best studied establishment factor. An early experiment suggested a maximum seeding depth of 5 cm for IWG, although 90% emergence was observed between 1.3-3.8 cm compared to 75% at 5 cm (McKenzie et al. 1946). Later experiments on seeding depth showed similar results, with IWG emergence being below 50% at 4 cm depth (Lawrence et al. 1991) or being significantly reduced below 5 cm although certain lines exhibited the potential for good emergence at lower depths (Lawrence 1957).

Generally, the experiments suggest that N and P fertilizer application as well as manure have a positive effect on both biomass and seed production (Canode 1964; Darwent et al. 1987), although irrigation was required to realize this benefit in Saskatchewan (Crowle 1966). In fact, under irrigated conditions, N-fertilization was observed to reduce seed production in the first two years before increasing it in the following three compared to the control (Crowle 1966). Because forage species tend to be grown under more marginal conditions or as an environmentally benign perennial grain (Wagoner 1990; Asay and Jensen 1996), there seems to be a tendency towards moderate input regimes (e.g. Black and Reitz 1969) . Landscape position may relate to the effect of manure application on seed yield where backslope positions experience a benefit while footslopes do not, even while biomass increases in both locations (Lee et al. 2009). Unfortunately Lee et al. (2009) did not offer an explanation for this result.

Row spacing was another parameter investigated by more than one study. Seed yields tended to be higher with closer row spacings (16-20 cm) (Black and Reitz 1969; Darwent et al. 1987), and subsequent experiments tended to use close row spacing when it was not tested as part of the experimental design (Wagoner 1989; Lee et al. 2009). Black and Reitz (1969) found that at wider spacing, fertilization had a much smaller effect and that seed yields were higher during dry years, suggesting that intraspecific competition for resources is likely significant under limited conditions. In contrast to the other studies, Crowle (1966) found a significant yield benefit of 90 cm compared to 30 cm spacing. Finally, as IWG stands become more established, biomass production for more widely spaced rows approaches closer spacings which may lead to similar total production in the long term (Darwent et al. 1987).

Seed yield often decreases as IWG stands age, shown by several multi-year trials investigating IWG seed yield (Green and Evans 1957; Canode 1964; Black and Reitz 1969; Wagoner 1990; Lee et al. 2009) though experiments explicitly addressing the issue in IWG are not common (Canode 1964). It appears as though it is possible to maintain yield to some degree through post-harvest intervention and managing vegetative growth. Canode (1964) found that burning stubble and mechanical thinning or control resulted in reduced tiller numbers and increased yields over control treatments, especially in the second and third years of production. Grazing with livestock, which has been suggested as a way of improving the economics of perennial grains (Watt 1989; Bell et al. 2008), has also been shown to result in higher seed yields for other grass species in subsequent years (Green and Evans 1957) although this effect is likely highly dependent on management (Fairey 2006; see 2.3.2 Livestock Integration with Seed Producing Crops). Grazing was also found by Wagoner (1990) to be superior to other methods of residue management that included mowing and burning although this may have been related to the fact that no fertilizer or nutrients were applied during this experiment.

2.3 Agronomic Strategies for Increasing the Sustainability of Perennial Grain Systems

2.3.1 Legume Integration and Management in Perennial Systems

Wagoner (1990) noted that perennial grain monocultures are not necessarily more sustainable than annuals given the susceptibility of monoculture systems generally to pests and continued reliance on exogenous nutrient input. Legume intercropping has been suggested as a way of maintaining and improving the N status of perennial grain systems and as a way of extending the benefits of perennials by increasing soil cover and biological diversity and reducing dependence on exogenous nitrogen inputs (Wagoner 1990; Crews 2005; Crews et al. 2016). Inclusion of legumes in a perennial grain system is expected to increase soil organic matter, enhance soil biological communities, and improve the timing of nutrient availability with crop demand although they also involve challenges such as competition with the main crop and immobilizing nitrogen as SOM levels increase (Crews et al. 2016). The long-term sustainability of legume inclusion is shown by a study documenting prairie grasslands maintaining a high level of N-export for more than 75 years (Glover et al. 2010).

Forage research suggests that legume intercrop systems are more sustainable and can be productively competitive with inorganic fertilizer additions. In a study looking at grass forage production under limited irrigation in Texas, N-fertilized grass monocultures initially outperformed legume-grass mixtures but there were no differences in total biomass production after the first year (Cui et al. 2013). Interestingly, although forb survival under drought stress is a concern (Cui et al. 2013), increased biodiversity has been found to result in greater production under stressful conditions (Prieto et al. 2015). IWG trials at the Rodale Institute tested intercrops of white clover (*Trifolium repens*) and birdsfoot trefoil (*Lotus corniculatus*) and found that growing IWG with white clover resulted in greater seed yield compared to IWG in monoculture (Wagoner 1990).

In aiming to quantify the stability of legume-grass pasture systems, Schulte (2001) identified several factors influencing the balance and fluctuations in biomass between white clover and perennial ryegrass (*Lolium perenne*), which included competition for light, the role of differing nitrogen sources, the delayed response to changing variables (e.g. nitrogen becomes available slowly with white clover tissue decomposition), grazing preference of livestock species, differing abilities to escape from grazing, changing spatial distribution of resources (e.g. locations of urine deposition being higher in available N), the invasion of other species, as well as random effects of climate variability. Many of these factors were also deemed relevant to alfalfa-grass mixtures, as well as the varieties used, planting pattern, seeding specifications, and defoliation regime (Chamblee and Collins 1988). This large number of factors is likely to make management of perennial grain-legume intercrops systems challenging, especially spread out over several years, and be highly dependent on the species present on the mixture.

For example, alfalfa can be a competitive species and has been shown to substantially increase its biomass relative to grasses when grown in mixtures after several years (Cui et al. 2013) to the point of eliminating them from the mixture (Chamblee and Collins 1988). Alfalfa has also been identified as the species driving biomass production in diverse polycultures, outgrowing IWG when the system is disturbed through multiple harvests in one season (Picasso et al. 2008). By contrast, sweet clover [*Melilotus officinalis* (L.) Lam.] has been observed to produce a large amount of biomass in the first year of seeding into grass mixtures, but then decline in production over time (Cui et al. 2013). However, Cui et al. (2013) found that grass production was higher in later years compared to alfalfa or sainfoin treatments, likely as a result of the increased availability of nitrogen through sweet clover tissue decomposition. In instances where sweet clover becomes well established, there may be significant competition for light given that it can reach heights of 2.9 m (Hoveland and Townsend 1985). Whereas IWG would have a lower competitive advantage under a greater defoliation regime typical of pasture or hay systems compared to alfalfa (Lawrence and Ashford 1966), greater disturbance may be beneficial for a low growing species like white clover, which often has difficulty competing with grasses (Rochon et al. 2004).

2.3.2 Livestock Integration with Seed Producing Crops

Promoting IWG and perennial wheat as a dual-use crop for both grain and forage production has been suggested as a way to improve the economics and increase adoption rates in order to enhance ecosystem service provision on a shorter timescale (Watt 1989; Wagoner 1990; Bell et al. 2008). Although apart from the initial Rodale Trials (Wagoner 1990) no integrated IWG-grazing studies have been published to date, simulated grazing experiments (clipping) investigating the effects of early-season defoliation are being performed at a number of locations in North America (Steve Culman et al., personal communication, November 4, 2015).

Though specific livestock-IWG integration experiments have yet to be published, other grass species have been integrated with grazing. The example closest to the current trials found that the IWG subspecies pubescent wheatgrass (*Thinopyrum intermedium* subsp. *barbulatum*) seed and biomass yields as well as maturity were significantly reduced by early season grazing, especially after the point of first hollow stem (Hopkins et al. 2004). This effect mirrored the results from earlier work showing decreased yields for winter wheat grazed early (Redmon et al. 1996). Similarly, late season grazing with sheep has been found to reduce seed yields for creeping red fescue (*Festuca rubra*) compared to flail or disc mowing treatments (Fairey 2006). Here the researchers attributed the reduction to livestock behavior: selective grazing that avoided any non-living material, and damage to plant growing points through hoof damage and close grazing. However, greater recruitment of reproductive tillers in red fescue has been associated with their production early in the previous season (Jonsdottir 1991), suggesting that late-season grazing would likely have a negative, species-specific effect on seed production the following year.

In spite of the above examples, other research has shown a neutral or positive response of both forage grasses and annual crops to livestock inclusion in the production system. A British trial involving different timings of cattle grazing on the seed production of four temperate grass species found that a single moderate grazing period of a few days resulted in the same or increased seed production compared to no grazing (Green and Evans 1957). More recently, keeping steers on pasture for 80 days resulted in significantly higher seed yields for tall fescue (*Festuca arundinacea*) in a drought year and no significant difference under typical conditions

(Santillano-Cazares et al. 2008). In Manitoba, an investigation into the effect of grazing pea-oat and oat green manures with sheep found no difference in subsequent crop yields and significantly increased nitrogen availability to 120 cm compared to ungrazed plots (Cicek et al. 2014).

The concept of grazing having a beneficial effect on multiple plant parameters, including seed production, has been established in other species (Paige and Whitham 1987) and is a foundational concept of Holistic Grazing Management (Savory and Butterfield 1999). The mechanisms behind such beneficial responses remain unclear, although some have suggested increased tillering post-grazing (Santillano-Cazares et al. 2008) or increased access to light resources (Aamlid 1993). In any event, it appears that timing, duration, and livestock species are key factors in determining whether livestock integration is detrimental or beneficial to perennial grain production.

2.4 Ecological Farming Systems

While farming systems aimed at improving the relationship between food production and environmental parameters share many of the same principles and practices, to a large extent they have cultivated their own communities and/or fields of research. Understanding food production through these various lenses is important in making sense of the variety of farm systems and practices that might fall under the blanket of 'ecological farming'.

The approaches to agriculture reviewed below include Conservation Agriculture (CA), organic agriculture (OA), Holistic Grazing Management (HM), and Permaculture, as well as some other influential North American farm systems. These disciplines were chosen because they largely cover the breadth of farming approaches on ecologically oriented Prairie farms. The purpose is to provide a rudimentary history, briefly discuss some of the associated criticism and benefits, and cover a number of practices that pertain to the approaches. The field of agroecology will also be discussed, particularly with respect to its capacity to unify and generalize the understandings of the other approaches.

2.4.1 Agroecology

Agroecology is a concept that developed over the course of the 20th century, built out of the realization that agricultural systems remain grounded within natural ecology (Wezel et al. 2009; Gliessman 2012). It is defined by Gliessman (2007) as "the science of applying ecological concepts and principles to the design and management of sustainable food systems" but has been expanded by Wezel et al. (2009) to include its dimensions as a movement and practice. Agroecology as a movement and set of practices has largely been tied to people in developing economies in the tropics, particularly Latin America, where there has been considerable resistance to the promotion of industrialized agriculture (Altieri 1989; Gliessman 2012) and a large set of traditional agricultural techniques that are native to tropical environments (Wojtkowski 2004; Altieri et al. 2015). By contrast, though it is well established in the scientific literature, agroecology is still relatively unrepresented in the public domain of developed economies (Ferguson and Lovell 2014) and interestingly the social movement aspect is not always represented - for example not being mentioned in a recent textbook (Martin and Sauerborn 2013).

Agroecology can be considered to apply wherever ecological processes relate to food production - including, for example, nutrient cycling, climate, soil characteristics and ecology, biodiversity, and pest management (Martin and Sauerborn 2013). In this respect, it encompasses the range of practices in other domains such as tillage reduction, rotation, and variety selection in annual grain systems (Wolfe et al. 2008; Davis et al. 2012; Palm et al. 2014) to livestock integration (Bonaudo et al. 2014) and agroforestry and water management systems (Wojtkowski 2004; Altieri et al. 2015).

2.4.2 Successional Spectrum

Though the application of agroecological principles can take place within (possibly) every food production system, its scope is normally limited to application within a particular production system (Davis et al. 2012; Palm et al. 2014) or introducing new elements within that context (Groot et al. 2010; Bonaudo et al. 2014). Crews et al. (2016) has suggested considering agricultural systems in terms of their stage of ecological succession, which may be a useful way of conceptualizing and designing farm systems through agroecological understanding.

Plant ecological succession can be simply understood as a pattern of transition from small-statured, short lived grasses and forbs colonizing a new or disturbed landscape, to larger, longer lived species (Smith et al. 2014) although it is a highly complex process affected by a large number of factors operating at multiple temporal scales (Walker and Wardle 2014). Grime (2002) has described the simpler pattern as moving from ruderal species, to competitors, and ultimately stress tolerant species. While there are a large number of factors influencing succession across large temporal and spatial scales (Walker and Wardle 2014), it may be most useful (at present) to employ a very simplified representation for the purposes of agricultural study.

Crews et al. (2016) compare early and mid-successional stages within the context of moving from annual to perennial grain systems, where significant environmental and sustainability benefits, such as reduced nutrient and pesticide inputs, improved soil health, and greater biodiversity are expected through mimicking Prairie ecosystems (Cox et al. 2006). Such benefits have been well documented even for the inclusion of perennial forages within annual rotations (Entz et al. 2002) and have long been recognized in the field of range management (Holechek et al. 2011). Though herbaceous perennial plants are considered the dominant form of vegetation among climax communities of grassland ecosystems (Smith et al. 2014), features of later-successional stages are often included in food production systems, both within (e.g. agroforestry) (Dawson et al. 2011) and outside crop areas (e.g. woodlots, hedgerows) (Groot et al. 2010; Lovell et al. 2010).

For the purposes of this thesis, the various agroecologically oriented approaches to food production will be linked by considering them in terms of how they relate to three simplified ecological states: ruderal systems (those involving regular disturbance resulting in secondary succession), herbaceous perennial systems (involving mainly perennial grass and legume species historically adapted to periodic disturbances such as fire or grazing), and woody perennial systems (including shrubs and trees). It should be noted that the application of woody perennials spans a significant range of species at different points of succession (Smith et al. 2014). Figure 1 offers a visual representation of this, as well as giving a sense of the focus of a few different approaches to food production.

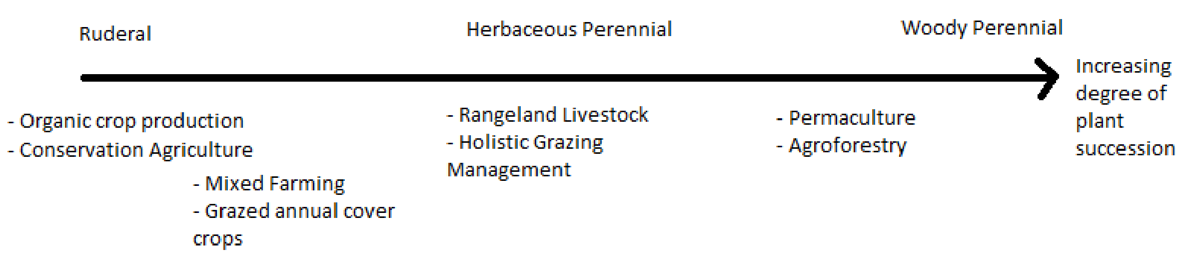

Figure 1. Representation of an increasing state of plant ecological succession, with some agroecological approaches to food production generally associated with those states below.

Here, CA and OA are considered to be primarily ruderal approaches, while HM and range management are at a herbaceous perennial level, and Permaculture is oriented towards systematic inclusion of woody perennial species even though there can be considerable overlap between approaches (e.g. mixed farming). Indeed, some very influential individuals in between or independent of these labels exist and are briefly described below.

2.4.3 Conservation Agriculture

CA and no-till farming have seen huge adoption rates across the developed and developing world over the past half-century (Kassam et al. 2009; Friedrich et al. 2012). Following its three principles of minimizing soil disturbance, keeping the soil covered, and emphasizing the importance of crop rotation, these systems have been shown to have a large positive impact on yields, moisture conservation, soil erosion, soil aggregate stability, carbon sequestration, and reduced disease vectors among others (Kassam et al. 2009; Verhulst et al. 2010; Palm et al. 2014). Beyond specialized equipment to minimize soil disturbance during seeding operations and crop rotation with legume inclusion, CA systems advocate for the inclusion of cover crops and green manures in order to maximize ground cover (Kassam et al. 2009). Cover crops and green manures are crops grown for the purpose of maintaining plant cover, increasing in-field biodiversity, and ultimately delivering organic matter and nutrients to the soil (Abdollahi and Munkholm 2014).

The technological advancement that has facilitated this approach and is tied to CA's rapid spread through industrialized agricultural economies was the development of the herbicide glyphosate and glyphosate resistant crops, which allowed for very effective weed control without tillage (Panettieri et al. 2013). However, the emergence and proliferation of glyphosate resistant weeds has sparked calls for improved management in CA systems and led to the reintroduction of older herbicides for weed management, which may be cause for concern over the long term feasibility of the approach (Christoffoleti et al. 2008; Beckie et al. 2014).

The rapid adoption of this practice, in spite of its fundamental differences from traditional forms of agriculture (Verhulst et al. 2010), has been a result of its immediately noticeable benefits in yield gains, environmental benefits, lower total input requirement and economic advantages, and that it requires relatively minor modifications to more conventional approaches in developed areas (Kassam et al. 2009; Friedrich et al. 2012).

CA is also promoted as an important way of increasing yields and food security levels in less developed countries. However, implementation has proven challenging in some areas due to low productivity and competing uses for crop residue (Erenstein 2002; Giller et al. 2009; Palm et al. 2014). Because such places often lack the capital for herbicide or machinery used in more affluent locations, CA has been adapted to minimize soil disturbance by hand-planting at planting stations or 'zai' (Kassam et al. 2009), but many of CA's benefits - including increased yields, reduced labor, and increased crop diversity - have come into question vis-a-vis its application in sub-Sarahan Africa (Giller et al. 2009).

2.4.4 Organic Agriculture

OA has greatly expanded and developed in practice, research, and the public consciousness over the past half century, driven by increasing concerns over chemical use and environmental sustainability (Lockeretz 2012). Through the principles of health, ecology, fairness, and care, regulated OA involves strict rules and certification procedures limiting the types of inputs and methods of production that can be employed in food production (CGSB 2015)

The strict limitations posed by organic certification standards has led organic grain production towards practices and research in a wide variety of agroecologically relevant techniques and approaches. Among them include diverse crop rotations that include nitrogen fixing legumes and/or perennial forage (Entz et al. 2002; Anderson 2015), cover crops and green manures , intercropping (Pridham and Entz 2008), and livestock integration (Cicek et al. 2014; Sempore et al. 2016). Unlike CA, OA remains at least somewhat reliant on tillage and cultivation for the control of weeds (Halde et al. 2015; Ruhlemann and Schmidtke 2015). In order to reduce the amount of soil disturbance associated with aggressive tillage, a wide variety of practices have been developed including mowing, rollers and roller-crimping, rod weeding, and pre and post-emergence harrowing (Frick 2013). In large part due to these practices, in addition to avoiding the use of synthetic pesticides and fertilizer, OA is associated with numerous environmental benefits, including increased biodiversity, improved soil properties, and reduced climate change impact relative to conventional (Scialabba and Müller-Lindenlauf 2010; Reganold and Wachter 2016).

However, OA remains somewhat contentious within broader society. Its claims of greater nutritional value have been contested (Smith-Spangler et al. 2012), although organic meat products are likely to have a more favorable fatty acid profile (Średnicka-Tober et al. 2016). It is also often criticized for having lower yields than conventional production methods (Connor 2008; Ponisio et al. 2015), something that has been observed in western Canada (Entz et al. 2001), when greater production is often argued to be necessary to sustainably support a growing global population (Connor 2008; Connor and Mínguez 2012) although this may not be the case in certain environments (Reganold 2012). Another weakness, particularly in light of CA and no-till, is the continued reliance of organic production on soil tillage for weed control (Halde et al.

2015; Ruhlemann and Schmidtke 2015). Finally, organic agriculture is associated with higher levels of human labor, which raises the dichotomy of both more vital rural communities as well as labor exploitation (Jansen 2000; Shreck et al. 2006).

2.4.5 Rangeland and Holistic Grazing Management

Unlike other agroecological farming strategies which have developed over time with important contributions from numerous communities and individuals, HM largely emerged from Allan Savory's experiences as a wild game manager in southern Africa (Savory and Butterfield 1999). Savory and Butterfield (1999) explain HM as a planning and decision-making tool that involves articulating lifestyle goals and evaluating decisions in light of those goals, assuming that these must ultimately be based in sustainable social, economic, and ecological environments. When applied to range management, HM is an approach to raising livestock for profit that involves integrated adaptive decision making and mimicking the behavior and effects of herds of large ungulates in prairie ecosystems. Savory came to understand the grassland ecosystem as being dependent on intensive animal disturbance followed by sufficient periods of rest, and has promoted rapid rotation of large numbers of animals through relatively small areas of pasture.

Savory's systematic approach to ecosystem management incorporates the social and economic aspects of sustainability in a way that explicitly avoids negative environmental externalities, always focused on enhancing the rancher's natural resource base. Whereas the discipline of agroecology teaches ecological processes and their importance but normally relates them to specific crops or practices (Martin and Sauerborn 2013), HM planning involves constant consideration of the effects of decisions on four large ecological processes (nutrient cycle, water cycle, community dynamics, and energy flow) in addition to their economic and social implications (Butterfield et al. 2006).

This approach is in stark contrast to the preferred management of grazing systems in the scientific literature (Briske et al. 2008; Briske et al. 2014). Well-managed rangelands have long been understood to provide a large number of ecological goods and services including carbon sequestration, increased biodiversity and wildlife habitat, water quality protection, and recreational value (Holechek et al. 2011). The literature suggests that the key to proper management of rangelands and pastures is by maintaining an appropriate stocking rate (animal units/acre/year) in order to prevent overgrazing (Briske et al. 2008; Holechek et al. 2011). Expectations that rotational grazing or HM intensive grazing would result in better distributions of palatable plants by reducing selective grazing, better plant health and productivity with larger rest periods, and positive effects on soil parameters have not been supported by grazing research conducted throughout the 20th and 21st centuries (Briske et al. 2008).

Nevertheless, when examining actual ranches, several studies have shown numerous benefits including increased stocking rate, improved plant species distribution, soil parameters, and financial stability (Jacobo et al. 2006; Teague et al. 2011; Ferguson et al. 2013). This discrepancy has been attributed to lack of adaptive management/treating grazing and rest as fixed treatments rather than variables, conducting experiments on unrealistically (and meaningfully different) small scales, and using animals that are not adapted to the management system (Teague et al. 2013).

Although sustainable range management and HM explicitly encompass a very wide range of livestock systems, they are also associated with practices meant to extend in-field grazing outside of the growing season. Such practices include bale, swath, strip, and stockpile grazing of cover crops, native pasture, or tame forage to enhance nutrient cycling, reduce feed and fuel costs, and lessen the need for and cost of manure transportation (Cicek et al. 2014; McCartney 2016).

2.4.6 Influential Individuals

One of the most influential figures in contemporary sustainable farming has been Joel Salatin at Polyface Farms in Virginia. His farming model is very similar to typical HM ranching systems in terms of intensive rotational grazing, but Salatin has incorporated multiple livestock species including poultry, pork, and rabbits in such a way as to minimize pests, cycle nutrients, and maximize grass production (Salatin 2010) which is closely associated with the theory and practice of Permaculture (Holmgren 2002; Shepard 2013). One of Salatin's defining characteristics is his focus on understanding the nature of the species he manages and applying that understanding to benefit both himself and his livestock and grass (Salatin 2010). Though the feasibility in terms of productive output efficiency for widespread replication of the system has been called into question (Meeh et al. 2013), many of its features such as chicken tractors/egg-mobiles, multiple species, and approach to direct marketing have been popularized as an attractive alternative to conventional production (Pollan 2006) as well as through Salatin's own publications (Salatin 2010).

A very different approach to ecological farming has been developed by North Dakota farmer Gabe Brown. Brown's system is a large scale combination of conservation agriculture, HM, and aggressively diverse cover crops with a high degree livestock integration (Barbercheck 2014). Though there does not yet appear to be published research examining the system, Brown claims to have eliminated the use of synthetic fertilizer, insecticide, and fungicide while using minimal amounts of herbicide in order to maintain weed control under the no-till regime (Brown 2016). Purported benefits of the system beyond significant inputs and energy savings include healthier soil, increased organic matter, healthier livestock, and improved yields and productivity (Brown 2016).

2.4.7 Permaculture

Permaculture as a concept originated through the collaboration of Australians David Holmgren and Bill Mollison in the late 1970s (Holmgren 2002; Ferguson and Lovell 2014). Although there is a diversity of conceptions and applications contained within the term, in large part due to its intentional diffusion as a grass-roots movement (Ferguson and Lovell 2015), Permaculture can be generally considered as a strategy to integrate human systems with natural ecology through the use of design in such a way as to minimize labor and energy inputs while maximizing ecological function (Holmgren 2002). Though it was informed and inspired by many of the sources, such as Rachel Carson (Carson 2002) and Howard Odum (Odum 1971), that had a strong influence on the philosophy of Wes Jackson and the development of OA, agroecology, and HM, Permaculture has also been strongly influenced by the work of P.A. Yeomans (Yeomans and Yeomans 1993; see 2.4.8 Farmscaping and management of non-field farm elements) and J. Russell Smith (Smith 1929). Notably, Holmgren and Mollison were strongly influenced by the concepts of Peak Oil and the work of Odum, leading them to an explicit preference towards low-energy solutions and self reliance (Holmgren 2002).

Permaculture has traditionally been practiced in home gardens and much of the writing has an urban focus (Hemenway 2009), but there has been increasing interest in and examples of its principles being applied at larger scales (Falk 2013; Shepard 2013; Doherty 2016). A number of influential writers and practitioners have emerged with somewhat distinct approaches and at different scales, some of whom have developed their own 'brands' of Permaculture. These include Sepp Holzer (Holzer 2004), Darren Doherty (Doherty 2016), Ben Falk (Falk 2013), Mark Shepard (Shepard 2013), and Michelle and Rob Avis in Western Canada (Avis and Avis 2012).

To date, Permaculture has received little attention from the scholarly community - especially in terms of agronomy and food production - often dismissed for being pseudo-scientific, impractical, and making unsubstantiated claims of effectiveness (Ferguson and Lovell 2014). This isolation from scientific inquiry has severely limited the understanding of the productive output and the ecosystem services of these systems, although an intensive investigation of a Permaculture-derived woody perennial system is ongoing at the University of Illinois (WPP Research 2015).

Although not discussed in detail here, Permaculture extends beyond food production and natural resource management into the built and social environments (Holmgren 2002; Falk 2013). The relationship of spatial elements to human actors, articulated through the use of the 'zone' concept, is another key consideration (Holmgren 2002; Hemenway 2009; Falk 2013). The intent is to increase self-sufficiency in a way that minimizes the labor and time necessary for the maintenance and operation of the system. Like agroecology, there has also been an increasing emphasis on the importance of the social and economic dimensions in the manifestation of its core principles (Holmgren 2002).

Despite the diversity among practices (Ferguson and Lovell 2015), Permaculture systems tend to share a number of biophysical features. These include a focus on perennial plant species, polyculture and diversity, successional planning, soil building, and landscape and water management through design and extensive planning (Ferguson and Lovell 2014).

Perennial plant species, polyculture, and succession are all central features as a result of the orientation towards mimicking natural ecosystems (Jacke and Toensmeier 2005; Hemenway 2009). Plant species are selected based on a number of multifunctional criteria that include productivity, nutrient uptake and nitrogen fixation, beneficial insect and wildlife value, growth habit, above and belowground interspecific complementarities, and local adaptation (Jacke and Toensmeier 2005). Using a high diversity of species and varieties within the same spatial area is meant to lower disease and weed pressure as well as result in overyielding (greater total yield of multiple species grown together compared to an equal acreage growing the same species in monoculture) through experimentation and conscious design of assemblages that minimize competition by occupying different canopy levels, root architectures, nutrient demands (Jacke and Toensmeier 2005; Hemenway 2009). Though the use of perennial species is heavily emphasized and encouraged, annuals are often incorporated into the systems, sometimes for their beneficial characteristics (vegetable gardens) (Falk 2013) but often as a method of generating yield and income as longer term successional elements (e.g. fruit or nut bearing trees) become established (Holmgren 2002; Shepard 2013). At a larger production scale, diversity is sometimes tempered in order to make the system more amenable to machine harvesting (Shepard 2013).

Successional planning is important as longer-lived species begin to change light and moisture conditions in the lower canopy, resulting in different species distributions (Jacke and Toensmeier 2005). Throughout this process, soil building through the application of mulch and inclusion of 'dynamic accumulators' (species that take up relatively large amounts of nutrients, often from lower in the soil profile) and nitrogen fixing species intended to be cut and mulched *in situ* complement the benefits of perennial plant cover in polyculture (Jacke and Toensmeier 2005; Hemenway 2009; Doherty 2016). System disturbance has been given some attention, especially for the maintenance of environmental heterogeneity, but its use appears to be mostly theoretical given the relative youth of most Permaculture systems (Jacke and Toensmeier 2005).

Landscape and water management are integral parts to Permaculture designs as well. Typically, water management strategies are pursued in areas with periodic deficits, catching and storing water through surface features and increased soil infiltration. Keyline planning (Yeomans and Yeomans 1993) is a very significant influence for many Permaculturists at larger scales (Shepard 2013; Doherty 2016), although these features are sometimes less systematically planned (Holzer 2004). Otherwise, especially at the home garden level, swales (small trenches excavated on topographical contour) are the predominant form of water capture, typically associated with trees for soil stabilization (Hemenway 2009). Wetlands or ponds are also used: in urban settings they are oriented towards more efficient use of household greywater; rurally they act as water reservoirs and opportunities for aquaculture (Holzer 2004; Hemenway 2009; Shepard 2013). In addition to water management, the landscape is also analyzed in terms of the spatial arrangement of elements and microclimate possibilities (Holzer 2004; Jacke and Toensmeier 2005; Hemenway 2009). The arrangement of elements (e.g. roads, fences, buildings, crop areas) is a key focus that is guided largely by labor and energy considerations, normally conceptualized by zone theory but also influenced by Keyline design, but also taking into account factors that affect property microclimates such as slope, aspect, proximity to water, and natural shelter (Doherty 2016).

Animal integration is an aspect of Permaculture that has not been discussed extensively in some major works (Jacke and Toensmeier 2005; Hemenway 2009), but is often found within farm-scale systems (Holzer 2004; Shepard 2013). Most species are integrated into the plant system in some way to serve functions beyond meat production, including disruption of pest cycles, enhancing land fertility (especially before establishing trees), and making use of excess or waste produce (Shepard 2013). Animals are typically integrated and rotated through the system, sometimes with the explicit influence of HM (Doherty 2016).

2.4.8 Management of non-field farm elements and farmscaping

Though the successional dimension of the various approaches to food production has vast economic and environmental implications, one further relevant dimension takes into account the features of the landscape not directly engaged in food production. The roles of these non-crop plant and landscape elements are often left out of farming system experiments (Davis et al. 2012; Pashaei et al. 2016), typologies (Alvarez et al. 2014), and farm system modelling efforts (Le Gal et al. 2011; Martin et al. 2013), but are the focus of the emerging field merging landscape ecology with agronomy (Ryszkowski 2002; Benoît et al. 2012) and have received explicit attention from Lovell et al. (2010) in a whole-farm context. Systematic consideration of these elements is common within Permaculture publications (Holzer 2004; Jacke and Toensmeier 2005; Hemenway 2009; Falk 2013; Shepard 2013).

Such elements typically involve afforested sections or water features, which, on the Canadian Prairies and elsewhere normally include shelterbelts, sloughs and wetlands (Tarnoczi and Berkes 2009; Bartzen et al. 2010) but may also involve ecobuffers (Schroeder 2012) or hedgerows (Groot et al. 2010). Farmscaping is a term, coined by entomological ecologist Robert Bugg, that can be used to describe the modification of farm characteristics beyond the field, particularly for, but not limited to (Martens et al. 2013) the purposes of promoting greater entomological biodiversity in agricultural systems (Bugg et al. 1998). The key insight of this approach is areas marginal to cash crop production can be planned or designed to offer enhanced multifunctional services. Ecobuffers in particular are meant to increase plant, insect, and macrofaunal biodiversity, enhance snow capture, reduce wind velocity, provide timber and non-timber forest products (including a diverse group of food producing species) (Schroeder 2012), contrasting with focusing on, in the case of shelterbelts, one or two services (wind protection and snow capture) and promoting only a few, fast growing, hardy species (Alberta Agriculture and Food 1992).

The marginal nature of many of these farmscape elements gives producers (and societies) the option of pursuing a number of the benefits of perennial plants and ecosystem services without radically changing their forms of production, leading Smaje (2015) to suggest that agroecological sustainability is best achieved through a 'weak perennial vision'.

Landscape modification for erosion control and water management is one that is strongly associated with farmscaping (especially wetlands, sloughs, and ponds), but can also be applied to the productive areas of the farm. Though there does not seem to be a consolidated body of literature addressing the general principles associated with the topic, it includes practices such as tile drainage and subirrigation (Nelson et al. 2011), contour farming and placing hedgerows on topographical contour (Black and Reitz 1969; Sun et al. 2008), terracing (Zhang et al. 2014) , swales (Hemenway 2009), and Keyline Farm design (Yeomans and Yeomans 1993). It is very closely related with the concept of increasing infiltration and water holding capacity of the soil using techniques such as cover crops or perennial forage (Blanco-Canqui et al. 2011; Pimentel et al. 2012), but is distinct in that it pertains to physical features and infrastructure that slow or hasten the movement of water across and away from the landscape.

Keyline design, invented by the Australian farmer PA Yeomans, offers the most systematic way of understanding and shaping the landscape for this purpose, i.e., efficient water movement (Yeomans and Yeomans 1993). Its approach in essence is to use a topographical contour map of the farm to determine appropriate locations for water storage ponds and irrigation channels, with implication for further farm design including dwelling and fence placements. It has been widely adopted and promoted within the Permaculture community, being an important influence since Permaculture's conception (Falk 2013; Shepard 2013; Ferguson and Lovell 2014; Doherty 2016). However, it is not well studied in the literature (a Web of Science database search for "Keyline" resulted only in a book review of the original publication) and one informal study focused on the cultivation aspect (Gilker 2013) . Nevertheless, a generalized understanding and planning the movement of water over a landscape through the use of topographical contour maps is likely to be important, particularly in light of drought and the projected effects of climate change (Siegfried et al. 2012).

2.5 Farm System Analysis

Although there is a considerable amount of published research relating to farming systems, several authors have argued for greater study of farms at a holistic, system level, especially those congruent with natural systems (Giampietro 2004; Gliessman 2012; Malézieux 2012; Cunningham et al. 2013; Thiessen Martens et al. 2013) . Similar to approaches of food production itself, farm analysis can take different forms and have different objectives. Some of these forms include farm typology (Madry et al. 2013; Alvarez et al. 2014), farm system design (Kropff et al. 2001; Davis et al. 2012; Martin et al. 2013), landscape-based approaches (Lovell et al. 2010; Benoît et al. 2012), and whole farm case studies (Murray 1994). The goals of such projects are usually ultimately oriented towards improving farm performance and farmer livelihoods (Le Gal et al. 2011), but can also be used to understand the economic and environmental implications of farming systems at higher levels of social organization (i.e.

scholarship and policy) (Giampietro 2004; Martin et al. 2013; Sylvestre et al. 2013; Alvarez et al. 2014). More directly, project objectives often involve helping develop or evaluate novel alternative farming strategies (Murray 1994; Kropff et al. 2001; Le Gal et al. 2011), using farm types to develop more specific and appropriate interventions (Righi et al. 2011; Alvarez et al. 2014), assessing the contribution of various multifunctional landscape elements to different farm parameters (Lovell et al. 2010), and improving the understanding of the interaction between productive, social, environmental, and economic factors at the management level (Murray 1994; Lovell et al. 2010; Gliessman 2012; Sylvestre et al. 2013).

The methods used for achieving these ends can be seen to vary along a spectrum that varies from being more heavily focused on quantitative, science-based research to qualitative, farmer-driven approaches (Figure 2).

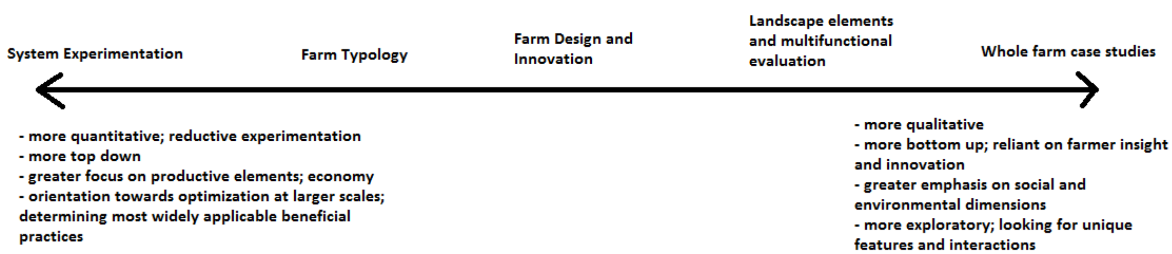

Figure 2. Scale of different approaches to the study of farm systems. Approaches vary from more scientist driven, reductive approaches (left) to more farmer driven, qualitative approaches (right).

A concept important to consider is that farm analysis, especially that which is oriented towards understanding and improvement at larger scales, often falls within the domain of post-normal science. Described by Giampietro (2004), post-normal science is the systematic process of making quality decisions in situations that involve complex, emergent systems where consequences are inherently unpredictable and there are multiple stakeholders that have equally valid yet differing values, needs, and understandings of reality (e.g. farmers, scientists, policymakers, future generations). It can be characterized as an iterative process that involves an ongoing dialogue between stakeholders, where reductionist scientific approaches are used to evaluate the feasibility of proposed solutions. Understanding farm systems within the context of post-normal science is important as agricultural sustainability relies on satisfying multiple stakeholders (e.g. farmers, the environment, governments) but valuable reductionist research is often directed by more influential groups towards increasing certain types of efficiency at the expense of others (Altieri 1989; Gliessman 2012).

2.5.1 Farm Design and Innovation

In the centre of Figure 2 are design and innovation approaches that may involve explicit collaboration between researchers and farmers, integrating modeling efforts, consultation, and on-farm experimentation (effectively bringing together both sides of the spectrum). Le Gal et al. (2011) suggests a 'design support process' that allows for the iterative development of farm models and systems based on farmer input. Farming system co-design in Manitoba is an example of such an approach (Entz et al. 2015). Similarly, Sylvestre et al. (2013) suggests combining different modeling approaches that are participatory, multi-scale, and integrate irreducible parameters, within the context of multiple possible future scenarios. Martin et al. (2013) reviewed farm design approaches with regard to computer modelling, distinguishing between more researcher driven models that look towards optimizing parameters within a closed problem space and more collaborative models which are less technical and where defining the problems is a more emphasized part of the design process.

2.5.2 Farm Typology

Farm typology is in some ways quite similar to design, but instead of using models to produce data to optimize or satisfy a wide number of parameters, it is more oriented towards characterizing farms using a minimal number of variables derived through statistical techniques such as principal component analysis and cluster analysis (Kobrich et al. 2003; Alvarez et al. 2014). The purpose of this approach is mainly to allow for improving the specificity and effectiveness of extension efforts as well as (similarly to farm design modelling approaches) predicting the effect of interventions on multiple scales (Alvarez et al. 2014). Unlike other methods where the effects of practices or design on biophysical or economic parameters are paramount, farm typology is more focused on general approaches and relies on surveys and census information as data sources (Tavernier and Tolomeo 2004; Righi et al. 2011) Though using expert opinion or qualitative methods are options, typologists strongly favor quantitative modeling approaches and multivariate analysis for greater reliability and reproducibility, as well as generating a more detailed level of understanding compared to quantitative approaches which tend to reflect geographical area (Kobrich et al. 2003; Madry et al. 2013; Alvarez et al. 2014).

2.5.3 Farm System Research Trials

At the far left of Figure 2 are more traditional quantitative experiments investigating the implications of alternative farm systems. System level experiments normally focus on the comparison of system-level farm strategies, such as crop rotation vs. continuous monoculture (Davis et al. 2012) or the timing of livestock management activities (Teague et al. 2013; Pashaei et al. 2016). Though they can generate large amounts of replicable data, developing general principles and understandings, and are incredibly valuable in understanding the effects and implications of many techniques, their general application is sometimes limited due by system or economic factors that are not considered (e.g. inability to soil surface mulch due to animal use) (Le Gal et al. 2011) and the scope and evaluation of the strategies can sometimes be narrow and skewed to favor certain classes of farmer (Altieri 2002).

2.5.4 Landscape Distribution-Based Studies

To the right of farm system design and innovation, examining farm landscape elements in a multifunctional context is yet another way of studying farm systems (Lovell et al. 2010; Benoît et al. 2012). Though modelling design methods are applicable in the landscape context (Groot et al. 2010), holistic evaluation of the various landscape elements can be challenging biophysically and be culturally subjective (Lovell et al. 2010). Here, in contrast with most typologies and experimental work, attention is placed on farm features that are not necessarily directly engaged in producing productive outputs, such as woodlots, hedgerows, or roads (Groot et al. 2010; Lovell et al. 2010). The value of such an approach is that a more complete understanding of the non-equivalent functions and features of the *entire* farm can be generated and evaluated, especially with regard to environmental sustainability where non-crop elements such as hedgerows or wetlands have a high degree of value (Bugg et al. 1998; Schroeder 2012). Various features can then be examined and potentially improved in terms of their economic, environmental, or social value (Lovell et al. 2010). However, such analyses are more site specific and valuations (particularly those that relate to culture and aesthetics) may be also individual specific (i.e. the farmer and surrounding community) (Bellet 2009), limiting the value of generalized models and quantitative analysis at the farm level.

2.5.5 Whole Farm Case Studies

Finally, whole farm case studies are meant to gather a very wide swath of information from farms that are deemed to be unique or exceptional. The main objective is to find and evaluate new information and techniques from exceptional farms, while holistically understanding the context that produced them and engaging with farmers to allow for more effective dissemination of the generated knowledge (Murray 1993). More so than other methods which typically produce 'exploitative innovations' that incrementally improve the performance of farm systems, this approach is oriented towards 'exploratory innovations' that offer fundamentally or radically different solutions to agricultural problems (Martin et al. 2013). Alternatively, the case study approach can be conceptualized as descriptive compared to the prescriptive nature of most agricultural research. It involves extensive collaboration between interdisciplinary researchers and farmers, and because much less is known by the researchers *a priori*, the quantitative research aspect is limited to biophysical measurements as opposed to hypothesis testing (Murray 1993). Quantitative modelling or typologizing efforts may not be as effective within this context due to low sample sizes and the high variability of farm systems under study (Murray 1993). The value of this approach is that it can help establish a context for the study of farming systems or techniques that are radically different from the dominant paradigm (Martin et al. 2013). It can also give insight into the social and economic dimensions of unique or poorly represented farm systems in ways that may not be apparent when engaged in a design support process. And innovation often comes from these “margins”; that is, underrepresented entities often hold clues to doing things better (Ljungblad and Holmquist 2007).

3.0 EFFECTS OF LEGUME INTERCROPPING AND RESIDUE MANAGEMENT ON INTERMEDIATE WHEATGRASS (*Thinopyrum Intermedium*) GRAIN AND BIOMASS PRODUCTION

3.1 Introduction

Growing perennial grain-producing species as a staple crop has been suggested as a solution to "the problem of agriculture" (Jackson 1980) because of their potential to eliminate or severely reduce many of the environmental sustainability issues associated with annual agriculture. By more closely mimicking grassland ecosystems by advancing the state of ecological succession (Crews et al. 2016), it is hoped that perennial grain systems will reduce the inputs necessary to make the system function, including fuel, fertilizer, and pesticides, reduce the rate of soil erosion by providing living soil cover year-round, reduce nutrient leaching into groundwater and increasing drought resistance through much larger root systems, enhance carbon sequestration and soil organic matter through reduced tillage and greater root growth, and provide better habitat for greater biodiversity (Crews 2005; DeHaan et al. 2005; Cox et al. 2006; Glover et al. 2010; Pimentel et al. 2012; Crews et al. 2016). These assertions have largely been supported by studies examining analogous systems (Culman et al. 2010; Glover et al. 2010; Bell et al. 2012), including work performed in Western Canada (Entz et al. 2001).

One of the methods for the development of perennial grain crops is the domestication of a new species (Cox et al. 2006; DeHaan et al. 2013). After extensive testing at the Rodale Institute, intermediate wheatgrass [*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey] (IWG) was selected as the best candidate for such domestication and has since been bred at the Land Institute and more recently at the University of Manitoba (Wagoner 1990; DeHaan et al. 2013). However, relatively little research has been performed so far on the agronomy of perennial grain systems, and it has been suggested that without a suitable system, perennial grains may not be any more sustainable than annuals (Wagoner 1990).

Two practices that have been suggested for increasing the viability of perennial grains are intercropping legumes to act as a long term nitrogen supply in lieu of inorganic fertilizer and the integration of livestock in order to improve the economics of the system, particularly while grain yields remain low (Wagoner 1990; Crews 2005; Bell et al. 2008). While livestock have sometimes been shown to have a deleterious effect in grass seed production systems (Hopkins et al. 2004; Fairey 2006), this is not always the case (Green and Evans 1957; Santillano-Cazares et al. 2008) and benefits such as improved nutrient cycling have been recorded in addition to the economic benefit of additional feed (Cicek et al. 2014).

The main objective of this experiment was to determine grain yields of IWG bred at the Land Institute and selected for adaptation to the Manitoba climate, looking at the effects of intercropping three different legume species and three alternative residue management techniques, including removal, chopping crop residue *in situ*, and livestock integration. It also looked at the treatment effects on IWG, legume, and weed biomass.

The main hypothesis for the legume treatments was that the legumes would make additional nitrogen available for the IWG, resulting in greater grain yield and biomass production than the control. A competing hypothesis for these treatments was the presence of the legumes would result in interspecific competition that should reduce IWG grain yield and biomass production. Finally, the presence of legumes should reduce the amount of ecological space available to other species by accessing more resources than IWG alone, resulting in lower weed biomass compared to the control.

For the residue management treatments, the primary hypothesis was that removing crop residue would reduce available soil nutrients while grazing would cycle them more quickly, resulting in lower yields for the removal treatment.

3.2 Materials and Methods

3.2.1 Site Description

The IWG experiment was conducted at the Ian N. Morrison Research Farm in Carman, MB, located in the Northern Great Plains of North America (lat. 49° 29'53"N, long. 98°01'47"W). The soil at this location is an orthic black chernozem and the climate is characterized by an average of 125 frost free days with 545 mm of precipitation (445 mm as rain) (Smith et al. 1998; Environment Canada 2016). Mean monthly temperatures and precipitation during the experiment for the 2014 and 2015 growing seasons is presented in Table 2.

Table 2. Mean monthly temperatures, precipitation, and long term averages for growing seasons at Carman, MB in 2014 and 2015 (Environment Canada 2016)*.

	April	May	June	July	August	September	October	Growing Season
Average Air Temperature (°C)								
2014	0.5	11.3	16.6	17.8	18.7	13.1	7.0	12.1
2015	5.5	10.7	10.7	17.5	18.3	15.8	7.2	12.2
Long Term Average[1]	4.5	11.6	17.2	19.4	18.5	13.4	5.4	12.9
Total Precipitation (mm)								
2014	40.1	30.9	116.7	27.6	122.4	46.3	6.0	390.0
2015	17.5	98.8	75.3	109.3	47.3	42.0	37.3	427.5
Long Term Average[1]	29.5	69.6	96.4	78.6	74.8	49.0	43.4	441.3

*7 days of data missing from Environment Canada in 2014

[1]30 year averages from 1980-2010.

3.2.2 Experimental Design

The experiment took place at one location with a split-plot randomized complete block design with four replicates. Total field size was 0.4 ha with a total of 48 plots that were 2 meters by 8 meters in size. Main plot treatments were legume intercrops while subplots were residue management. The legume intercrop treatments consisted of the legumes alfalfa (*Medicago sativa*), yellow sweet clover [*Melilotus officinalis* (L.) Lam.], white clover (*Trifolium repens*), and a control (no intercrop) while residue management treatments were chopping and leaving the crop residue in situ, removal of crop residue, and chopping residue followed by grazing with Dorper sheep (*Ovis aries*).

The experiment was conducted under dry-land organic conditions without inputs of any kind, including inorganic fertilizer or pesticide, manure, compost, or rock-based fertilizer.

3.2.2.1 Seeds, Seeding and Sources

The IWG seeds were taken from samples of seeds produced at the Ian N. Morrison Research Farm by Douglas Cattani (University of Manitoba) grown from a selection of plants provided by the Land Institute (Salina, KS) after the third round of selection and FUSDA-GRIN germplasm. These materials were selected for surviving two months of winter and for high seed yield in the first year of reproductive growth before being used for the experiment. IWG was planted on August 28th, 2013 with a Fabro custom seeder (Fabro Enterprises Limited, Swift Current, SK). Seeds were planted in rows 15.2 cm apart, seeding rate was 8.3 kg/ha, and depth was approximately 1.9 cm with depth bands attached to the seeder.

Legume species used for the experiment were alfalfa (c.v. Caribou), sweet clover (c.v. Norgold), and white clover (common). The legumes were planted between IWG rows on May

10, 2014 with a 15.2 cm row spacing. Depth bands were attached to the seeder to restrict depth to 1.9 cm. However, it is likely that depth was slightly shallower due to the previous August seeding and drier than normal spring conditions creating firmer seedbed.

3.2.2.2 Harvest Details

The field experiment was swathed on August 18th, 2014 and combined on September 7th under moderately damp conditions. In 2015, swathing took place on August 18th. IWG swathing was conducted with a R-TECH custom made 2m wide swather (R-TECH Industries, Homewood, MB).

The IWG was combined by a Kincaid Massey Harrison 8XP combine (Kincaid Equipment Manufacturing, 210 West First St. P.O. Box 400, Haven, KS 67543), which also chopped wheatgrass residue for chopped and grazing treatments. Field combining took place on September 7th, 2014 and August 27th, 2015. For the residue removal treatment, wheatgrass straw from the back of the combine was removed by hand on September 11, 2014 and August 28 in 2015.

3.2.2.3 Grazing Details

The grazing residue treatment was only applied to the experiment in 2014. Designated plots were grazed by sheep between September 11 and September 15, with pre-grazing beginning on the 11th and the sheep being moved every 24 hours from replicates 1 through 4 between the 12th and 15th.

A total of 8 sheep were split into four groups, where each plot was grazed by 2 mature ewes for 24 hours. Sheep were conditioned to the wheatgrass by spending 24 hours in a pre-graze plot before entering the first replicate. Because there were no noticeable differences between the grazing pattern/evenness of the pairs of sheep, the sheep were kept within a particular legume treatment to maintain consistency. For example, the pair of sheep conditioned on the alfalfa treatment pre-graze were kept in only alfalfa plots for each replicate.

3.2.3 Data Collection

3.2.3.1 Biomass Sampling

A summary of the information pertaining to the sampling points of the experiment is given in Table 3. Plots were sampled via random method throughout the experiment, except for the samples taken for the 2015 harvest due of the possibility of reusing previously sampled locations. One m^2 sites were selected on May 8th, 2015 to avoid points sampled pre- and post-graze, end of season, and during June 2015. However, it is unlikely that this precaution was necessary due to the uniform growth of the grass at harvest time. All biomass samples were conducted using hand scythes and quadrats, taking all of the vegetation down to the soil surface.

For samples taken pre-graze, post-graze, and end of season biomass in 2014, brown matter and litter was removed from the soil surface to determine differences between residue management (especially grazing) but because the sheep consumed almost no brown matter (including that which was standing) and the difference between biomass removal and chopping were large (see results). In 2015, only standing biomass was measured.

Table 3. Summary of experiment sampling dates. Dates in parentheses indicate reweighing due to improper sampling or uncertainty over results. Biomass was measured for intermediate wheatgrass, legumes, and weeds (all non-wheatgrass or legume plants). The treatment column indicates the relevant treatment factors at the time of sampling.

Sample Date	Size	Processing	Drying	Weighing	Title	Treatments
Aug 17, 2014	2 × 0.25 m^2	19 Aug	Sept 2- 4	4 Sept (Feb 5, 2015)	Yield and Biomass	Legume
Sept 11 - 14, 2014	2 × 0.25 m^2	Mid-Sept	Sept 19-22	22 Sept (July 16, 2015)	Pre-Graze Biomass	Legume
Sept 12-15, 2014	2×0.5 m^2	Mid-Sept	Sept 19-22/25-29	Sept 22/Sept 29	Post-Graze Biomass	Legume
Oct 21, 2014	1×0.25 m^2	Oct 23-28	Oct 29-Nov 3	Nov 3 (July 16, 2015)	End of Season Biomass	Legume + Residue
May 6 and 8, 2015	various	-	-	-	Tiller and Legume Counts	Legume + Residue
June 4, 2015	2 × 0.25 m^2	June 5-6	June 6-8	June 8	Early Season Biomass	Legume + Residue
July 29, 2015	1 m rows	-	-	-	Reproductive Tillers	Legume + Residue
August 13, 2015	1×1 m^2	August 19-21	August 21-24	August 24, 26 (September 9)	Yield and Biomass	Legume + Residue
October 14, 2015	1×0.25 m^2	Late October	Oct 27-31	Oct 31	End of Season Biomass	Legume + Residue

3.2.3.2 Processing and Drying

Biomass samples were sorted by hand into intermediate wheatgrass, legumes, and weeds/other. Wheatgrass was further sorted between green (growing) and brown (old and lignified) biomass for pre- and post-graze and the end of season biomass for both 2014 and 2015.

Once processed, all samples were dried in an oven at 65°C for at least 48 hours. In cases where old samples needed to be resorted, the reprocessed samples were dried again at 65°C for at least 24 hours.

3.2.3.3Seed Processing and Cleaning

Once harvested, sorted, and weighed, yield samples were threshed by a Wintersteiger Classic plot combine (Wintersteiger AG, Dimmelstrasse 9 4910 Ried/I. Austria). Concave clearance was set between 3 and 4, fan speed was set at approximately 680 (2014) and 660 (2015) RPM, and a cylinder speed between 700 and 710 (2014) and 720 (2015) RPM.

After combining, seeds were cleaned with a LA-L5 no. LA L5-0019 Westrup Seed Cleaner (Westrup A/S, Soroevej 21 DK-4200 Slagelse, Denmark). This took place on October 9, 2014 and between October 26 and 30th, 2015. The top screen used clipper adapter #3 with #13 round sieves, middle screen used clipper adapter #2 with 7/64 × 3/4" rectangular sieves, and a very fine mesh used for the bottom screen. The seed cleaner was run at 319 RPM, with air level A = 3.25 and air level B = 2 to maximize the amount of seed collected. The Triac control, which sets the rate of input from the vibration feeder, was set between 4 and 5. Samples were pre-sieved to remove the majority of the straw still present in the samples.

Final seed cleaning took place on January 29, 2015 and during November 2015. Samples were passed through a rectangular 5/64×3/4" sieve followed by a round 6/64" sieve. The 2014 samples were passed through the round sieve multiple times while in 2015 the rectangular sieve was used twice per sample and the round was rarely employed. This was mainly due to the greatly reduced number of small weed seeds present in the samples.

Final seed weights were not measured as bare seed, with approximately 50% still having lemma and palea attached. Dockage and ergot levels were not measured.

3.2.3.4 Tiller Counts, Legume Cover Estimation, and IWG Nutrient Content

Tiller counts were performed on May 6 (vegetative) and June 9 (reproductive) in 2015 to determine whether grazing had an effect on tillering and reproductive induction (Table 3). Two 1 m rows of tillers were counted *in situ* on each date.

Estimations of legume plant populations were also made on May 6, 2015 (Table 3). Different methods were used for each species given their habit and prevalence. Because the number of white clover stems was too great to count in a relatively large area but was often patchy, the percentage of area covered by white clover within one row of IWG was measured by recording the length of white clover presence for the entire length of each plot. Because alfalfa presence was relatively consistent but more manageable, the number of stems between rows of IWG were counted and converted to stems/hectare. Due to the very patchy nature of the sweet clover, stem counts were performed using 1 m^2 quadrats and converted to stems/ha.

Finally, although soil nutrient levels were not measured during the experiment, the IWG biomass samples taken during June 2015 were sent to Agvise for a complete tissue nutrient analysis. The entire 0.5 m^2 samples containing only IWG were sent, after sorting, drying and weighing.

3.2.4 Statistical Analysis

Treatment effects were tested using analysis of variance for all measurements. Statistical analysis was performed using the GLIMMIX procedure of SAS 9.3 (SAS Institute 2012). The Tukey-Kramer method was used to determine significant differences between treatments ($p=0.05$). Assumptions of the analysis of variance were tested using the Univariate procedure to assess whether data and residuals were normally distributed, Bartlett's test was used through the

GLM procedure to assess homogeneity of variance between the treatments, and the Plot procedure was used as a method to visualize the residuals.

Logarithmic transformations were performed prior to analysis for variables that did not conform to the assumptions of the model. These variables included legume biomass, weed biomass, and white clover cover. Constants were added to these when zero values were recorded.

3.2.5 Issues

Sorting errors were likely the greatest source of inaccuracy for the project. The difficulties inherent to this task were species identification and complete sorting. Species identification should not have created a major issue, although it became apparent that IWG and foxtail species in particular were often difficult to distinguish without reproductive structures. This most likely resulted in greater IWG biomass being recorded but was probably consistently treated for each sampling period. Sorting the samples completely into component species also proved difficult due to the large number of very small tillers, seedlings, weeds, weed seeds, and legumes. This was typically dealt with by visually estimating the relative proportions of the various components and separating the mixed pile accordingly.

Green biomass from the pre-graze and end of season sampling in 2014 was reweighed due to concerns over the original measurements. Some biomass was lost during the reweighing, mostly affecting samples with larger amounts of biomass with the likely effect of reducing the variability between the measurements.

There were also problems with sorting biomass during both years. In August 2014, biomass samples were sorted into only IWG and weeds where only reproductive tillers were considered to be IWG. This problem was recognized in 2015 and the 'weed' samples were resorted into IWG, weeds, and legumes. Though the samples had been dried, sorting remained possible though some visual estimation was used to apportion legume and weed leaves and seeds due to the high degree of mixing. For August 2015, many of the samples were not sufficiently sorted between the three categories and required resorting as well. All samples were re-sorted in order to maintain uniformity. Fortunately, in this case the problem was recognized before the samples were dried.

Ultimately all samples were treated the same - those samples that did not require further sorting were all removed from bags and visually inspected like those that did. One of the consequences of re-sorting and reweighing the legume samples was that samples with a large amount of biomass tended to lose more in the weighing process than small samples. This would have lowered the amount of variability between legume biomasses, but is very unlikely to have had a material effect on the results given that larger samples were orders of magnitude greater and losses were less than 1 g (i.e. 0.2 g compared to 198 g).

For many of the sampling points during the experiment, weed and legume biomass levels were very low (and often not observed) - especially in comparison to the amount of IWG present. However, this low level of biodiversity is likely important to quantify in the long run especially where perennial legumes take several seasons to become fully established (e.g. the slow increase of mean white clover biomass). The height of the legumes, particularly of white clover which often stayed very close to the ground under IWG, also makes it difficult to fully collect with a hand scythe and quadrat - which may have resulted in slightly underestimating the total biomass.

3.3 Results

As a note to the reader, the results and discussion below contain numerous observational statements regarding trends in the data that are not statistically significant, more so than normally encountered in scientific writing. The underlying rationale is that such observations might provide some preliminary background for further investigation due to the current paucity of work in perennial grain agronomy.

3.3.1 Grain Yield and Harvest Index

The overall mean IWG grain yield was 519.9 kg/ha in 2014 and 446.8 kg/ha, decreasing by 14% between the two years (Table 4). There were no significant differences among the legume treatments in either year, although in 2014 there was a 38% difference between the lowest treatment mean 427.5 kg/ha (sweet clover) and the highest at 689.5 kg/ha (white clover) (Table 4). Observationally, both treatments had a comparatively higher standard error (131.8 and 106.5 respectively) than the alfalfa and control treatments (52 and 72.5). In 2015, it was observed that all mean yields were lower except for sweet clover which increased slightly by 29.3 kg/ha.

Table 4. Mean intermediate wheatgrass grain yield by legume and residue management treatment for 2014 and 2015.

Treatment	2014	2015
	kg/ha	
Alfalfa	482.5	419.6
Control	480.0	421.5
Sweet Clover	427.5	456.8
White Clover	689.5	489.2
Grazing	n/a	518.7 a[y]
Removal	n/a	406.3 b
Chopping	n/a	415.3 b
Overall	519.9	446.8

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

The grazing residue management treatment resulted in a significantly higher grain yield than the removal and chopping treatments (p=0.0095) (Table 4). No interaction between the treatment levels was observed. Possible explanations for the higher yield include greater production of biomass and increased numbers of reproductively induced tillers although these are not supported by the results (see below). Alternatively, grazing may have provided a timely increase in the amount of nutrients available or decreased early-season light competition may have allowed for greater reproductive investment (see 3.4.3 Residue Management).

Looking at yield in terms of harvest index, the results remained largely consistent. An interesting difference was that the alfalfa harvest index was close to white clover in 2014 (7.27 vs. 7.29 %) (Table 5) though the mean yield was of the alfalfa treatment was lower and closer to the control (482.5 vs. 480.0 kg/ha) (Table 4), suggesting that the alfalfa may be reducing IWG production through competition. Again, the only treatment that resulted in a significant difference was grazing compared to removal or chopping.

Table 5. Mean harvest indices by treatment for 2014 and 2015, excluding and including legumes in total biomass.

Treatment	2014 No legume	2014 With legume	2015 No legume	2015 With Legume
	----------------------------	----%	----------------------	
Alfalfa	7.27	7.19	5.47	4.92
Control	6.42	6.42	5.81	5.81
Sweet Clover	6.05	5.71	5.58	5.39
White Clover	7.29	7.28	5.80	5.63
Grazing	n/a	n/a	6.60 a[y]	6.32 a
Removal	n/a	n/a	5.39 b	5.14 b
Chopping	n/a	n/a	5.01 b	4.86 b
Overall	6.76	6.65	5.66	5.44

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

Harvest index that includes legume biomass is included in Table 5, as this was an intentional part of the production system. In 2014, the greatest difference in harvest index between excluding and including the legume was for sweet clover with a decrease of 0.34%, reflecting the higher sweet clover biomass produced. In 2015, larger decreases in harvest index were observed in alfalfa (0.55%), reflecting its higher biomass production compared to the other legumes (Table 5).

3.3.2 Plant Biomass

IWG biomass production was fairly consistent over the course of both years (Table 6). There was a slight observed increase in biomass at harvest (August) where 7544.6 kg/ha was produced in 2014 and 7967.3 kg/ha in 2015. Similarly, end of season biomass was lower in 2014 than 2015 (625.0 to 649.1 kg/ha). The sampling point with the least biomass was immediately before the application of the grazing treatment in September 2014 (mean biomass = 360.8 kg/ha), which took place only three weeks after harvest. The majority of the biomass (average 5616.3 kg/ha) was produced between early June and mid-August.

Table 6. Mean intermediate wheatgrass biomass for legume and residue management treatments at all sampling points during the experiment.

	2014			2015		
Treatment	August	September	October	June	August	October
	kg/ha					
Alfalfa	6717.5	314.0	607.3	2345.8	7451.7	604.5 ab
Control	7445.0	454.5	607.7	2336.3	7474.8	779.7 a
Sweet Clover	6740.0	297.5	624.7	2462.8	8497.0	668.0 ab
White Clover	9275.5	377.0	660.3	2259.2	8445.9	544.3 b
Grazing	n/a	n/a	312.8 b[y]	2260.1	8009.7	601.5
Removal	n/a	n/a	762.3 a	2387.8	7678.8	691.3
Chopping	n/a	n/a	800.0 a	2405.3	8213.5	654.6
Overall	7544.5	360.8	625	2351	7967.3	649.1

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

Significant differences between treatments at the p=0.05 level of significance were found for the October sampling points in both 2014 and 2015. In 2014, the grazing treatments resulted in significantly lower IWG biomass compared with the other treatments. This result was expected given the complete consumption of growing biomass by the sheep in September leaving only approximately a month for regrowth. In October 2015, the white clover treatment produced 325.4 kg/ha less IWG biomass than the control (p=0.012), which may have been related to higher white clover competition compared to the other legumes. This may have come as a result of the white clover being less disturbed by the seed harvest event (i.e. less defoliation by cutting; see 3.4.3 Residue Management)

A point of potential interest is that the standard error associated with the sweet clover treatment was observed to be higher than the other treatments for both August sampling times as well as in June 2015. In several plots the sweet clover established poorly or not at all (see 3.4.2.1 Sweet Clover) but in others it grew very well, which would have created a wide range of levels of competition with IWG and made the results more variable.

Weed biomass was aggregated with IWG for September 2014 with the expectation that the sheep would consume all growing plant matter, which proved to be the case. For October 2014, the data were not analyzed because weeds were absent in most plots and recorded biomass was very low (≤ 40 kg/ha).

Weed biomass was also observed to decline greatly from an overall mean of 1023.9 kg/ha in August 2014 compared to 88.0 kg/ha in August 2015 (Table 7). An ANOVA indicated a significant difference ($p<0.002$) between the two sampling dates, with an overall mean difference of -1051.7 kg/ha.

Though not significantly different from the other treatments in terms of biomass produced, alfalfa was the only treatment that did not show an increase in weed biomass between June and August 2015 (Table 7). A further ANOVA test of the difference between the weed biomass for June and August 2015 showed a significant difference between the alfalfa and sweet clover treatments ($p=0.048$).

Table 7. Mean weed biomass by legume and residue management treatment in August 2014 and all biomass sampling points in 2015.

	2014	2015		
Treatment	August	June	August	October
	kg/ha			
Alfalfa	1285.7	50.2	41.8	9.2
Control	1247.3	49.4	80.6	9.2
Sweet Clover	994.0	37.4	192.8	13.9
White Clover	689.6	30.5	89.6	24.1
Grazing	n/a	70.6 a[y]	152.0 a	19.4
Removal	n/a	33.8 b	79.9 ab	9.6
Chopping	n/a	28.8 ab	57.4 b	12.0
Overall	1023.9	41.0	88.0	13.1

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

Again, grazing treatment showed a significant difference between the other residue management treatments. In June 2015, weed biomass in the grazing treatment was greater than removal (p=0.027) and then chopping (p=0.043) in August. It is worth noting that all treatments had very low weed competition compared with annual organic grain systems (Cicek et al. 2014; Welch et al. 2016).

Legume biomass production during the experiment seemed most affected by legume species. There were no significant differences between residue management treatments, although biomass levels in the grazing treatment went from quite a bit lower than removal and chopping in October 2014 (similar to IWG biomass) to higher in August and October 2015 (Table 8). The overall mean biomass increased between years for August and October, which likely reflects the increased presence of both alfalfa and white clover compensating for the lower levels of sweet clover.

Table 8. Mean legume biomass by legume and residue management treatments for all biomass sampling points during the experiments.

	2014			2015		
	kg/ha					
Treatment	August	September	October	June*	August	October
Alfalfa	58.0 b[y]	46.0	30.9	111.8 a	469.0	321.2 a
Sweet Clover	377.4 a	not observed	12.8	13.3 b	61.5	8.8 b
White Clover	20.1 b	45.5	40.1	8.0 b	107.8	172.4 a
Grazing	n/a	n/a	9.0	23.3	204.9	107.5
Removal	n/a	n/a	39.2	37.7	176.8	88.6
Chopping	n/a	n/a	39.8	22.1	95.7	87.9
Overall	76.1	45.8	26.0	27.1	150.6	94.3

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance. *indicates a significant interaction between treatment levels

In 2014, there was significantly more sweet clover than either alfalfa or white clover (p=0.005) which showed the rapid establishment and growth of the biennial compared to the perennials. However, by June 2015 there was significantly more alfalfa present than either sweet clover or white clover. Though there were no significant differences between legumes during August 2015, by the end of the season alfalfa and white clover were both significantly greater than sweet clover.

The interaction between legume type and management was caused by differences in the way the legumes responded to residue management in the fall of 2014 (Table 9). While white clover biomass was unaffected by residue management, alfalfa biomass was reduced with grazing and chopping and sweet clover biomass was reduced with grazing.

Table 9. Legume biomass means for the interaction between legume and residue management treatments, intercropped with IWG for the 2015 biomass sampling dates.

Legume	Residue	June	August	October
		--------------------kg/ha------------------		
Alfalfa	Grazing	113.6 ab[y]	705.4	354.3
	Removal	242.4 a	605.5	323.8
	Chopping	47.9 abc	239.6	282.1
Sweet Clover	Grazing	2.2 c	31.8	6.0
	Removal	20.3 bc	178.4	7.9
	Chopping	24.1 abc	36.4	13.0
White Clover	Grazing	14.5 c	373.2	261.5
	Removal	4.2 c	46.2	150.6
	Chopping	6.7 c	91.9	129.2

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

3.3.3 Legume Cover, Tiller Counts, and Nutrient Data

Estimation of early season legume populations were performed in May 2015 to assess the potential impact of the residue management treatments. The legume treatments themselves are not treated due to the different methods of data collection (especially white clover where stem counting would have been very impractical). Alfalfa and white clover were relatively well established, being readily visible in most plots while sweet clover was difficult to find and often absent, as further evidenced by biomass data collected later in the season. However, analysis showed a significantly higher number of sweet clover stems/m^2 for the chopping treatment compared to the grazed plots (p=0.034) (Table 10).

Table 10. Mean legume cover values, intercropped with IWG, by residue management treatment measured in May 2015. Different methods of measurement were used due to species distribution and characteristics.

Treatment	Alfalfa	White Clover	Sweet Clover
	---stems/m²--	---% cover--	---stems/m²--
Grazed	141.1	13.2	0.5 b[y]
Removal	93.5	7.1	7.0 ab
Chopping	132.9	11.0	10.0 a
Overall	122.5	10.1	5.8

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

No significant differences were found among treatments for the number of tillers counted in May or reproductive tillers counted in June (Table 11).

Table 11. Mean IWG tiller counts from May 2015 and reproductive tillers from June 2015 by legume and residue management treatments.

Treatment	May	June Reproductive
	----------tillers/m²-------	
Alfalfa	522.3	462.3
Control	606.6	532.0
Sweet Clover	527.7	484.2
White Clover	483.0	418.3
Grazing	495.5	466.8
Removal	589.6	503.2
Chopping	522.6	448.9
Overall	533.3	472.4

Overall there was little treatment effect on the IWG nutrient concentration in June 2015 (Table 12). A significant difference between the graze (0.167%) and chopping (0.182%) treatments was observed for calcium only (p=0.04). Given the consistency among other nutrients, it seems most likely that this result is a type I error. No significant differences were found among any of the micronutrients (data not shown).

Table 12. Mean, oven-dry IWG macronutrient contents in June 2015 by legume and residue management treatments.

Treatment	N	P	K	S	Ca	Mg
	-------------------------------			%	----------------------------	
Alfalfa	1.88	0.158	1.91	0.095	0.176	0.100
Control	1.88	0.159	1.92	0.097	0.173	0.100
Sweet Clover	1.96	0.158	1.99	0.098	0.175	0.101
White Clover	1.80	0.156	1.88	0.091	0.172	0.098
Graze	1.88	0.156	1.93	0.096	0.167 b[y]	0.098
Removal	1.84	0.154	1.89	0.093	0.173 ab	0.100
Chopping	1.91	0.163	1.95	0.096	0.182 a	0.102
Overall	1.88	0.158	1.92	0.095	0.174	0.100

[y]Means within a column followed by the same letter are not significantly different according to Tukey-Kramer comparisons at 0.05 level of significance.

3.4 Discussion

3.4.1 Overall Yield

While still lower than economic threshold levels of approximately 580 kg/ha over 8 years (Watt 1989) or consistent yields around 1.2 to 1.4 Mg/ha in good quality soils (Bell et al. 2008), the yields for the present experiment (519.9 and 446.8 kg/ha) were comparable with yields reported in the literature (Table 13), especially considering the lack of fertilizer input or irrigation.

It is worth noting that an earlier seeding date may have resulted in higher yields for the 2014 sampling date. IWG is typically seeded in the spring or late summer prior to the first production year, where better yields are associated with earlier seeded stands as a result of greater resource accumulation and tiller development (Doug Cattani, personal communication, July 11, 2016) that allow for greater reproductive induction over the winter (Heide 1994).

Table 13. Intermediate wheatgrass yield, biomass, variety and location, reported by other field studies.

Study	Grain Yield (kg/ha)	Biomass yield (kg/ha)	Variety	Location
Black and Reitz (1969)	<200 - 350 (5 year average)	2000-3500	Not reported	Sidney, Montana
Darwent et al. (1987)	548 (3 year average)	3480	Chief	Beaverlodge, AB
Wagoner (1990)	566 (year 1) 157 (year 2)	Not reported	Oahe	Kutztown, PA
Lee et al. (2009)	148-242 (year 2); 35-82 (year 3)	5000-5900	Oahe	Brookings, SD
Canode (1965)	459 (5 year average)	Not reported	Greenar	Pullman, WA

The observed decrease in yield from 2014 to 2015 is consistent with most results pertaining to IWG (Lee et al. 2009; Wagoner 1990; Canode 1965). However, this year over year decline varies quite a bit among the sources, where Darwent et al. (1987) and Canode (1965) were able to maintain relatively high yields over several years while Wagoner (1990) and Lee et al. (2009) reported large drops within the first few years. Yield maintenance for the present experiment appears to be more in line with the earlier group, although it has been reported that seed yields typically exhibit a large reduction in the third year (Canode 1965).

As a note, IWG biomass production for this experiment was in general much higher than literature values, with averages between 7500 and 7900 kg/ha (Table 6). It seems probable that this was a result of the IWG being grown under more favorable climatic and soil conditions than other seed production studies who reported biomass of around 3500 kg/ha in Montana (Black and Reitz 1969) or the Peace Country (Darwent et al. 1987).

3.4.2 Legume Treatments

The overriding theme from the legume treatment aspect of the experiment was that there was no evidence to support that there was increased nitrogen availability compared to the control. The lack of significant differences in yield and biomass, as well as the nitrogen content in the IWG sampled in June 2015 (Table 12), except for in October 2015 where the control produced significantly more IWG biomass than the white clover treatment (Table 6) (see 3.4.2.2 White Clover), suggests that either nitrogen is not currently a limiting nutrient in the system or that the legumes have not contributed meaningful amounts to the soil.

However, it seems likely that the legumes will play a larger role in terms of nutrient dynamics as the system ages. The nitrogen contribution should become increasingly obvious over time, especially compared to the residue removal treatment. This pattern has been documented when looking at the long term nitrogen export of native grasslands (Silvertown et al. 2006; Glover et al. 2010) and is also an important factor in determining the balance between grass and legume biomass (Chamblee and Collins 1988; Schulte 2001) What will be interesting to compare is how the biennial sweet clover compares to the perennial legumes (alfalfa and white clover). After the completion of its life cycle, sweet clover should decompose and release its nutrients more quickly than the perennials. This expectation is supported by Cui et al. (2013) who found that after high initial sweet clover biomass production in a bluestem grass mixture, grass production was higher in subsequent years compared to perennial legumes alfalfa and sainfoin that occupied a much greater proportion of the total biomass. However, its relative difficulty in re-establishing in the second year of the present experiment (Table 8), possibly due to grazing defoliation or competition with IWG (see 3.4.2.1 Sweet Clover), may mean that there will be a reduced effect in older stands.

Though there may be nutrient contributions in the longer term, the lack of an effect after two years may have implications for the design of perennial grain systems. In a stand managed for 8 years (Watt 1989), including legumes would likely be very cost effective but a more recent and in-depth analysis assumes a longevity of between 2 and 6 years (Bell et al. 2008). This indicates that legume intercrops may not be ideal as a nitrogen source, especially where inter-specific competition has a negative effect on yields. In shorter-lived stands it may end up being more economical to apply inorganic fertilizer or growing an N-fixing green manure before establishing IWG, although greater soil nitrogen levels have resulted in higher weed pressure (Wagoner 1990). However, it is very possible that the observed nutrient dynamics will change substantially as the soil system approaches a new equilibrium in terms of soil organic matter caused by reduced soil disturbance and extensive root growth (Crews et al. 2016).

Another aspect of the legume intercrop system that was not observed was its response to stress, especially drought. Authors have found that increased diversity does not always result in greater productivity (Picasso et al. 2008) but that benefits associated with increased plant diversity are more evident under suboptimal conditions (Prieto et al. 2015). It would be interesting to observe the response of the legume-intercrops compared to the control under drought conditions to determine whether such a biodiversity effect would be important. This effect may also be magnified when combined with livestock integration, which improved the seed production of tall fescue (*Festuca arundinacea*) in a drought year (Santillano-Cazares et al. 2008). The primary driver of yield increase for Santillano-Cazares et al. (2008) appeared to be a higher level of reproductive tillering, which was not observed for the present experiment (Table 11) even though there was significantly higher yield (Table 4).

Finally, there was some expectation that presence of seeded legumes would have had a suppressive effect on weed populations, but no significant differences between the treatments were observed. In the first year, the best candidates for weed suppression appeared to be sweet clover, which produced a relatively large amount of biomass (Table 8), and white clover (see 3.4.2.2 White Clover).

As a passing observation, competition from IWG appeared to have a strong suppressive effect on weed biomass, with the overall mean weed biomass shrinking from 1023.9 kg/ha in August 2014 to 88.0 kg/ha in August 2015 (Table 7). Though residue management had significant effects on weed biomass (Table 7), weed biomass was 1.1% compared to the overall mean IWG biomass (7967.3 kg/ha), excluding legumes, which raises the question of whether weed management (especially annuals) is relevant for the system in subsequent years. Continued weed monitoring in the longer term will be important to determine how perennial weeds interact with the system.

The discussion below covers some of the unique aspects of the different legumes. While it is based on the analyzed data, the reader should note that all of the legumes were quite variable in terms of their presence - often ranging between zero and nearly 2000 kg/ha (data not shown). This pattern is more often encountered in the ecological literature and is generally attributed to the patchy nature of resource distribution (Fletcher et al. 2005). For agricultural production, more uniformity is generally preferable so further exploration of the inter-specific plant dynamics and resource partitioning, especially with regard to the closeness of already established plants (Ross and Harper 1972) would be useful in developing a longer-term perennial intercropping system.

3.4.2.1 Sweet Clover

In contrast with the observed decrease in IWG seed yield across all other treatments, yield for the sweet clover treatment remained constant (427.5 in 2014 and 456.8 kg/ha in 2015 (Table 4). However, the 2014 yield was much lower than the other treatments (minimum difference 52.5 kg/ha). It is most likely that the significantly higher production of sweet clover biomass in 2014 compared to the other legumes (Table 8) resulted in greater competition with IWG and suppressed yield somewhat. In 2015, sweet clover biomass was greatly reduced or did not regrow in many plots (data not shown) which would have reduced competition and allowed for a higher yield compared to the previous year. It is also possible that sweet clover senescence resulted in greater tissue breakdown and nutrient release compared to the other treatments, also helping maintain yield.

The amount of sweet clover itself that was produced was quite variable. After establishing well after seeding in 2014 (Table 8), it did not re-emerge in several plots which was very surprising given that sweet clover is generally expected to grow very well in the year following establishment (Hoveland and Townsend 1985). A possible explanation may relate to below-ground interspecific competition with IWG, as both species have extensive root systems that extend deep into the soil (Hoveland and Townsend 1985; Cox et al. 2006). The variety used for the experiment, 'Norgold', has been noted to have less spring vigor in its second season, which may have made it more vulnerable to competition from IWG (Goplen 1981).

The reduced presence of sweet clover appeared to be especially true in the grazed plots, where there was a significant difference between early season plant count treatments (Table 10). This difference may have been caused by the grazing disturbance reducing the survival of the established plants, more so than the other legumes. The plants could have also been impacted by having fewer root reserves for winter survival and regrowth after both harvest and grazing disturbances. Further factors including competition with IWG and growth stage at the time of harvest might also have played a role. In conclusion, the dynamics of the sweet clover treatment were inconsistent for this trial and more intensive management or experimentation is likely necessary in order to produce more conclusive results.

3.4.2.2 White Clover

A feature of the 2014 data was the comparatively high IWG biomass (9275.5 kg/ha) and seed yield (689.5 kg/ha) for the white clover treatment (Tables 4 and 6). This may be associated with the lower weed biomass in these plots (689.6 kg/ha) compared to the next lowest - sweet clover (994.0 kg/ha) - which also produced significantly more legume biomass (Table 8). Interestingly the harvest index was comparable to alfalfa (7.29 vs. 7.27 % when not including legumes) (Table 5). This pattern suggests that even though white clover production itself was low, it may have had an suppressive effect on weed populations that allowed for greater IWG production in comparison to an intercropped alfalfa. This difference would likely be related to the prostrate growth habit of white clover occupying more ecological space than a taller growing alfalfa, as well as its patterns of rooting depth and water use (USDA-GRIN; Michaud and Richard 1992).

Fascinatingly, there was significantly less IWG biomass produced in the white clover treatment compared to the control in October 2015. Though not significantly different from the alfalfa treatment, which was next lowest, it is remarkable that the IWG biomass went from being consistently larger than the other treatments to the lowest at the final sampling point (Table 6). In contrast to the other legumes, white clover biomass was observed to have increased between August and October 2015 (Table 8). Although legume height data were not collected, it was seen that the low-growing white clover was not cut by the harvesting equipment which would have given it a comparative advantage over the other species, which had to recover following the swathing event. The low level of IWG biomass in October may be a result of relatively higher competition with the white clover due to the loss of its canopy advantage and better white clover establishment - even though alfalfa biomass at that time was as great or greater (Table 8).

3.4.2.3 Alfalfa

In 2015, the most obvious pattern among the legume treatments was the increasing biomass and competitiveness of alfalfa. Producing the largest amount of legume biomass at all three sampling dates, significantly so for June and October, there was also considerably more than in either August or October 2014 (58.0 kg/ha in August 2014 compared to 111.8 kg/ha in June 2015) (Table 8). This increased biomass produced the largest decrease in harvest index (0.55% compared to a change of 0.19% for sweet clover) and likely contributed to the not-significantly lower yields and biomass production compared to the other legume treatments (Table 5). Intriguingly, in contrast with all other treatments where the weed biomass doubled between June and August 2015, the alfalfa weed biomass was observed to decrease slightly (Table 7) and changed significantly less than the sweet clover treatment, giving further evidence of its competitiveness.

Given that the alfalfa was observed to be increasing in dominance over the system up until the final sampling date, it is unclear when or whether the system will reach a fairly stable equilibrium point although literature suggests that alfalfa will likely dominate the system in a low nitrogen environment (Chamblee and Collins 1988; Silvertown et al. 2006). Visual observations of the experiment in the spring and summer of 2016 suggested that alfalfa had become the primary contributor to biomass in those treatments. Though white clover shows a similar pattern of establishment, it seems doubtful that it is capable of major competition with IWG because of its growth habit (USDA-GRIN).

3.4.3 Residue Management

The most striking result among the residue treatments was the significantly higher yield for the grazing treatment compared to removal and chopping (518.7 vs. 406.3 and 415.3 kg/ha Table 4). This result remained consistent when looking at harvest index and harvest index with the inclusion of legume biomass (Table 5). While this may have been a result of timely nutrient availability due to greater nutrient cycling, supported by studies reporting an increase in yield as a result of fertilizer (Canode 1968; Black and Reitz 1969; Lee et al. 2009), the experimental data shows that there was no significant increase in IWG biomass (Table 6) or nutrient content (Table 12) which would have supported this explanation. Another possible mechanism is that grazing, especially early grazing, might stimulate further production of inducible tillers (Paige and Whitham 1987; Santillano-Cazares et al. 2008). However, there were no significant differences found between counts of vegetative tillers in May or reproductive tillers in June of the year following grazing (Table 11) that would support this hypothesis.

The higher yield as a result of grazing contrasts with Fairey (2006) who found that grazing with sheep uniformly reduced seed production for creeping red fescue (*Festuca rubra*). The sheep grazing behavior was similar in that they ignored brown stubble and consumed all of the growing material and the sheep were grazed for a comparable amount of time (20 hours vs. 24 hours). The main difference was the stocking density (0.011 sheep/m^2 for Fairey vs. 0.125 sheep/m^2).The authors conjectured that the negative impact of the sheep was most likely due to close grazing or hoof action damaging the plant crowns. For the present experiment, the sheep were closely contained and often observed to be resting (low hoof action) which may not have been the case with a larger herd grazing a much larger area. It is also possible that IWG responds differently to grazing than red fescue - other research has demonstrated that certain species are highly adapted to grazing and exhibit many positive responses as a result of actual or simulated grazing (Paige and Whitham 1987)

In spite of this disagreement, other researchers have observed increases in grass seed production systems following the establishment year for numerous species (Green and Evans 1957) and under drought-stress conditions (Santillano-Cazares et al. 2008). Santillano-Cazares et al. (2008) suggested that a significant increase in reproductive tillers may have been due to plant bases being more exposed to light in the grazed treatments, lending support to this mechanism as a source of yield increase, which is consistent practices used to maintain yields that involve biomass removal (Canode 1964; Aamlid 1993).

Though grazing did not have any evident effect on IWG biomass production (with the exception of October 2014), it did have a significant effect on weed biomass and appears to have interacted with the legume species in different ways. Weed biomass for grazing was higher in both June and August 2015 (Table 7) though not consistently so compared to either removal or chopping. Though this result was unexpected, it is not altogether surprising given the almost total removal of all growing biomass in September 2014. This removal reduced the biomass (Table 6) and some of the competitive advantage of IWG and the legumes into the spring of 2015, allowing for more weed establishment - although still much lower than 2014 (Table 7).

The legumes appeared to be affected differently by the grazing treatment. Sweet clover appeared to be the most negatively impacted and both visual field observations and samples indicated that it did not re-establish in most of the plots that had been grazed (data not shown). This observation is supported by the significantly lower number of sweet clover plants counted in the grazing treatment compared to chopping in June 2015 (Table 10). This may be because the sweet clover was more palatable and susceptible to grazing damage than the other legumes, although whether this related to physical damage to the crown or repeated disturbance post-harvest is unclear. In contrast, grazing did not appear to have a lasting negative effect on either the alfalfa or white clover biomass produced compared to the other treatments (Table 8).

Similarly to the legumes, the main expectation related to the residue treatments pertained to nutrients and nutrient availability. Removing the IWG straw after harvest should result in a much higher export of nutrients, which, in a no-input system should reduce its productivity. In comparison, grazing with sheep was expected to cycle nutrients more quickly by breaking difficult to digest cellulose in the rumen more quickly than soil-based microbial decomposition.

However, again like the legume treatments, it is unclear whether nutrient dynamics played a role in the first two years of the system. The most likely treatment to have a major effect on this short time-scale was grazing through faster nutrient cycling, which is supported by the significantly higher yield (Table 4). On the other hand, this is not supported by IWG nutrient concentrations in June (Table 12) or by significantly greater IWG (Table 6) and legume biomass production (Table 8). This evidence suggests that the observed differences are more likely to be the result of plant responses to grazing and physical characteristics of the soil cover - especially their effects on legume production. It is also possible that an increased availability of nutrients earlier in reproductive tiller development may have been a factor in the increase.

Valuable information could be gained by extending the study, especially by grazing over multiple years. However, in order to isolate the reasons behind the increase in IWG seed yield as a result of grazing a second experiment would likely need to be performed. Important treatments to include would be simulating the disruptive behavior of sheep (i.e. biomass removal and hoof action) without the addition of nutrients, and the addition of nutrients without the disruptive behavior through manure or fertilizer. More extensive data should be collected on soil nutrient concentrations at different points in the experiment to monitor their availability at different points of the season and testing of more reproductive characteristics (e.g. seed size, seeds per seedhead) used to determine what contributor to yield is being affected.

3.4.4 Tiller Counts and Nutrient Concentrations

Vegetative and reproductive tiller values were similar to Canode (1965) whose IWG culm counts ranged from 409 to 503 culms/m^2 in the third year of the experiment but were much lower than Mitchell et al. (1998) who reported values from 1381 to 1954 tillers/m^2.

Meanwhile, nitrogen concentrations were most comparable to concentrations of 1.9% for treatments fertilized at 89.7 kg N/ha (Dotzenko 1961) and higher than Black and Reitz (1969) who found concentrations ranging from 1.32 to 1.58%. P concentrations also were comparable to literature values, where a concentrations ranging from 0.02 to 0.2% were found in a laboratory experiment examining the effect of P removal after certain dates (Boatwright and Viets 1966) and again somewhat higher than for Black and Reitz (1969) where values ranged between 0.129 and 0.135%. Black and Reitz harvested their material at the early bloom stage, which was a later stage of growth than the samples taken on June 4, 2015, so it is not unexpected that their N and P concentrations were lower.

3.5 Conclusions

While forming conclusions based on a short term study may be risky for many types of agricultural research, it is particularly evident here, where many of the anticipated effects of a perennial grain system are expected well outside the time-frame of this thesis. Additionally, the observed trends should be considered with caution given the relative paucity of research and well-articulated theories in the areas of legume inclusion and livestock integration. Extensive further research will be necessary to truly understand the complex dynamics and species interactions between plant, animal, and management.

With that said, the establishment success of all of the legumes should be appreciated by the reader. Being seeded 8 months after the IWG would have given them a considerable competitive disadvantage, potentially to the point where they would not have developed into an appreciable component of the system.

3.5.1 Short term system dynamics

Overall, expectations that nutrient presence and availability would be noticeably affected by the different treatments - N contribution by legumes, nutrient cycling by sheep, lower nutrients for the removal treatment - were not supported by nutrient concentrations in June 2015 or biomass production for IWG, weeds, or legumes.

Instead, most of the significant effects and patterns among the data seem to be related to either interspecific competition or ecological space. Evidence for competition comes mainly from the end of the experiment, where larger alfalfa and white clover biomass appears to be having a negative effect on IWG growth. However, further evidence of competition between species can be inferred from the observed maintenance of IWG grain yield for the sweet clover treatment which was accompanied by a large reduction in sweet clover biomass between 2014 and 2015.

Among the treatments, it appeared as though grazing with sheep created the most ecological space. This was most evident through the significantly increased weed biomass compared to the other residue management treatments. Trends within the data suggest that grazing may have had a positive effect on alfalfa and white clover production (when not regrazed the following year) as well.

Grazing also appeared to have a physiological effect on the component species in different ways. The most notable was the significantly higher IWG grain yield without a corresponding increase in biomass. Grazing also had a differential effect on legume production, where sweet clover was observed to have been eliminated while alfalfa and white clover seemed to benefit. For alfalfa and sweet clover, ecological space may again be a more important factor as the results for alfalfa in 2015 were very close to the removal treatment.

A point of interest that may warrant further investigation was the apparent success of the white clover treatment in terms of weed suppression and greater IWG biomass and yield in 2014. If such an effect exists it may have ramifications for the economics of the system during the first year of production. Given the evidence of increasing white clover competition with IWG in October 2015 (Table 6), it might be advantageous to continue to fall graze the white clover in order to reduce its comparative advantage derived from being less disturbed by the grain harvest event (see 3.4.2.2 White Clover).

Another worthwhile comparison would be to re-establish the experiment seeding IWG early in the growing season, such as May or June, rather than August. It seems probable that this would result in greater yield in the first year of production in addition to less weed competition, and may also have implications for how the legumes behave in the system.

3.5.2 Future Dynamics

Despite the lack of differences in the first two years, it seems very likely that nutrient-related differences between the treatments will emerge eventually. The control with residue removal treatment combines a lower degree of nitrogen fixation with the removal of a large amount of biomass, which contrasts greatly with the other treatments. However, the longer term dynamics of legume and weed production within the context of residue management remain unclear. Examples include the degree to which alfalfa will compete with IWG and whether an equilibrium will be established, and whether weed biomass will increase in the system as perennial weeds become more prevalent.

A parameter to study as the experiment continues would be the soil quality. The removal and grazing treatments result in less soil cover than chopping even though the system is not tilled, while the presence of legumes may also have effects on various soil characteristics.

4.0 ECOLOGICAL FARMING SYSTEMS ON THE CANADIAN PRAIRIES

4.1 Introduction

Agroecology, "the science of applying ecological concepts and principles to the design and management of sustainable food systems" (Gliessman 2007), is a powerful way of approaching and resolving many agricultural challenges, particularly with regard to the environment. However, although it can be seen as an enveloping term that applies to a wide range of food production techniques and approaches (Wojtkowski 2004; Altieri et al. 2015), it has not spread widely into popular culture in North America compared to scientifically marginal yet innovative approaches such as Permaculture (Ferguson and Lovell 2014). Furthermore, many agroecological (and otherwise) techniques have been developed and are practiced in tropical latitudes (Holmgren 2002; Wojtkowski 2004; Altieri et al. 2015) and the degree to which these concepts might be applied within the context of the Canadian Prairies is unclear and unknown.

The objective of this study was to gain information on innovative agroecological practices and farming systems on the Canadian Prairies. More specifically, knowledge about a range of types of food production, including OA, HM, and Permaculture was sought by identifying and interviewing several farmers on the Canadian Prairies that self-identified or were identified as 'ecological' or 'ecologically oriented', i.e. using food production concepts and ideologies that value ecological processes and natural diversity, with the goal of environmental sustainability. The methodology used to answer this question was a series of farm case studies at different locations in Alberta, Saskatchewan, and Manitoba. The interviews were meant to capture a holistic picture of the farms with a focus on their farming systems and a case study approach was used to present this information.

4.1.1 Project Justification

Though this project does not involve a replicated study or a large enough sample size upon which to perform meaningful statistical analysis, it nonetheless has some scientific value. Its most direct contribution is in providing observational background for the study of unconventional, field-scale food production practices - especially in establishing that they are practicable and potentially economically viable on the Canadian Prairies. This allows for future hypothesis development and testing for both evaluation and improvement in agricultural systems which might otherwise be of little immediate relevance. A possible example would be a taungya system where field crops are initially intercropped with immature crop producing tree species, gradually phasing out the field crops as the trees begin to produce (Wojtkowski 2004).

The project is also meant to begin to take into account (successfully or not) challenges posed by authors arguing for a more complex understanding of agricultural systems, from dealing with non-reducible parameters (e.g. ecosystem services vs. farm revenue) and reducing the number of unacknowledged assumptions that are often hidden within 'objective' reductive science (Giampietro 2004), to dealing with the importance of including the social and economic ramifications of changing agroecological practices (Gliessman 2012), to thinking about how to better mimic natural ecosystems in agriculture (Malézieux 2012). Though still very rudimentary, the approach of the current project is meant to develop an understanding that encompasses a holistic view of farming systems. This view includes the non-biophysical connections and landscape elements in addition to production (Lovell et al. 2010) consistent with the process of generating identities for further analysis associated with post-normal science (Giampietro 2004) (see 2.5 Farm System Analysis) ultimately directed towards better decision making at farm, research, and policy levels.

The most promising alternative approach that would be replicable and quantitative is questionnaire or survey. These are typically used when developing farm typologies (Alvarez et al. 2014), which are a form of farm analysis that has bearing on the present project. However, typologies are generally performed when farm practices and strategies are well understood (Righi et al. 2011; Madry et al. 2013). Little was known about Prairie Ecological farming before the interviews were conducted, so using a rigid framework that did not allow for adjustment would almost certainly have missed important information for the understanding of the systems - especially with regard to the details of system management (e.g. tillage regime, pork habitat). For this reason, the general approach exemplified by Murray (1993) seemed best suited for the present project though limitations in terms of time and manpower make a thorough inquiry unfortunately impractical.

4.2 Materials and Methods

4.2.1 Participant Selection

Farms were identified mainly by using advertisements in the various provincial Organic association newsletters and the Alberta Eco-Ag group. Additionally, farms were identified through professional contacts (Mark Wonneck and Joanne Thiessen-Martens), however most of those identified professionally also responded to the advertisement (with one exception). Two of the participants were contacted based on the advertisement alone and two potential farms were contacted but not interviewed due to time constraints.

Though there were no strict guidelines for the selection of participants, there were numerous criteria and considerations. General criteria included willingness to participate, self-identifying as ecologically oriented, having farming constitute a significant portion of income, and having a land base greater than about 4 ha. It was also important that the farm system to include more than one ecologically oriented practice (e.g. intercropping, mob grazing, agroforestry), which was normally identified by the professional contact. For farms that were not known beforehand, a short description of the farm operation was asked for in order to determine whether the case-study would be appropriate.

As the project aimed to capture the variability of ecological farming systems on the prairies, further considerations were to look for a range in farm environments/climate and regional representation, farmer demographics, and types of farming system (e.g. livestock, organic). However, due to of the low numbers of potential participants, these considerations did not play a large role in selection.

4.2.2 Contact and Human Ethics

After having identified participants that suited the criteria and were willing to participate through phone or email, a copy of the consent form describing the purpose and plan of the project was sent via email along with the list of interview questions (see 7.3 Appendix C and 4.2.4 Interview Questions). In brief, the farmers were informed of their right to withdraw from the study at any time and promised results of the study, including write-ups of interviews where the farmer's consent was obtained.

4.2.3 Interview Plan

The case studies involved two main activities: in-person interviews guided by a prepared questionnaire and farm tours. Additionally, 8 hours of labor were offered as compensation for participation in the project. This would have the additional benefit of allowing for additional, first-hand observation of the farm systems.

Because the study was meant to acquire as much novel information as possible, questions were not limited to the questionnaire and topics were explored as appropriate. With regard to ecological understanding in particular, questions were meant to gage farmers' working understanding to gain a sense of what their priorities are more than the extent of their knowledge.

It was anticipated that the interviews would take approximately 3 hours to complete plus the length of the farm tour.

Interviews were recorded with a recording device as well as handwritten notes. Due to the long length of the interviews and the large amount of information, only the notes were used in preparation of the results.

4.2.4 Interview Questions

In order to gain a holistic understanding of the farm systems under study, the interview questions (see 7.4 Appendix D) were designed to gather information covering a wide range of topics (Table 14).

Table 14. Topics intended to be addressed by farm interview questions.

- farmer demographics	- farm environment and characteristics
- infrastructure, labor and inputs	- agro-ecosystem components
- management practices	- ecosystem understanding
- learning and thought processes	- biophysical and economic performance
- social and economic strategies	

Given that it was unknown how the farmers would respond to the questions, and the expectation that there might be a wide range of types of answers within certain topics (e.g. learning and thought processes), the questions were not tested beforehand. However, the farmers were sent the list of questions in advance of the interview and asked to respond if they had any issues or questions of their own.

4.2.5 Actual Methodology

After making contact with farmers in early 2015, an interview schedule based on farm location was arranged with the farmers (primarily via email) and most farms were visited during June 2015 (Table 15). The numbers used in Table 15 denote the order in which the farms were interviewed. Letters were randomly assigned to the participating farms for the discussion to help ensure farm anonymity (see 4.2.7 Farm Anonymization). Only 10 of the farms ended up being included in the discussion either because of time constraints or dissatisfaction with the information collected.

Table 15. List of dates detailing when all farms were visited and interviewed. Farms 1, 3, and 9 ultimately decided to not participate in the study.

Farm	Interview Dates
1	June 2
2	June 8-9
3	June 11-12
4	June 14-15
5	June 16-17
6	June 18-19
7	June 21
8	June 24-25
9	June 26
10	June 29
11	June 30
12	July 20
13	Oct 19

Overall, the interviews and farm tours were much longer than expected, typically taking at least 8 hours to complete. Though the planned schedule was to conduct the interview and tour over one day and work on day two, several interviews spanned both days. In these cases there were typically activities (often involving the author) taking place in addition to the interview, which involved gaps and intermittent answers. Interviews tended to take less time towards the end of the interviews, which suggests that the process became more efficient with practice.

One practical problem was that notes were not always taken when they should have been: often casual conversation would include insights and opinions relevant to the study, especially before the interview began. Taking notes during the farm tours often did not happen as well - it was anticipated that this information would be covered in the interviews themselves but was often not the case in practice.

As more interviews were conducted, issues with the list of questions became evident. In several cases questions were passed over because the interviewee had already discussed them in answering another.

In contrast, there were certain topics where more questions would have been appropriate. The most important areas were the 'systems' used by the farmers to raise either their crops or their livestock. Though the interview questions seem to cover this in a broad way (i.e. Are there any specific methods or techniques that you use on your farm? If yes, how have they been applied and what adaptations have you made?), it became clear through the interview process that the details of the system (e.g. pigs raised in pens vs. bush; winter grazing strategies; tillage regime for crops) were very important distinctions in terms of the operation of the farm and particularly in discerning practices that help (or hinder) the success of the farm. This became clear relatively early in the interview process, but because it was not added to the list of questions, this issue was not addressed in a systematic way which resulted in having uneven documentation of these systems.

4.2.6 Farm Case Studies

Initially the case studies had been conceived as short summaries discussing the relevant details of each farm with the purpose of presenting the information in a way that could be useful primarily to the participants and other producers but also to scientists and the broader public. Because there was a large amount of uncertainty over what type of information the project would generate, no predesigned framework was developed.

It is important to note that the information in the case studies is almost entirely farmer derived and approved. Their understandings or knowledge may not be factually or scientifically correct and there was no ground-truthing apart from visual evidence given by the farm tours. It is also possible that certain parts of the write-ups were deemphasized where the author did not agree with the rationale behind a viewpoint (consciously or unconsciously). This problem would likely have been attenuated with at least one more interviewer taking notes (Murray 1994). Nevertheless, given the constraints and goals of the project, this problem is relatively minor.

The write-up process began after interviewing Farm 11 and continued for the next 6 months. Instead of summaries, they became reorganized transcriptions of the notes that included pictures, diagrams, maps, and occasional author observations where appropriate. As a result, these write-ups became quite extensive and can be found in 7.4 Appendix D where farmer consent has been granted. The length of the case study varies with the farm, ranging from approximately 5,000 to 13,000 words.

The reason that this approach was taken was that it seemed to be important to keep the farming systems and innovations within their context. Presenting the farms only as their productive, economic, and biophysical elements would have vastly undervalued the importance of background, environment, life stage, and personal characteristics in the development and maintenance of these systems. This in turn would reduce the project's relevance for interested farmers, readers, and researchers (particularly those more interested in economic or social sustainability). Furthermore, (in principle) attempting to preserve the information gathered in the interviews allows for the future possibility of alternative reductions of the information based on different purposes or assumptions.

A challenge of the write-ups was keeping an appropriate level of detail, particularly when discussing farm details. The main factor here was farmer response which depended on their knowledge (particularly area history, environmental details, and often forage yields) and their inclination to discuss the details of their management strategy given the lack of official questions in this area. With regard to management techniques especially, the objective was to strike a balance between being too vague (e.g. "I graze annual cover crops") and too detailed (e.g. cover crop seeding rate, depth, time, exact timing of grazing events). While not necessarily allowing for the immediate application of a certain strategy, knowledgeable readers would likely be able to approximate them or the principles behind them with some success while the casual reader would not be overwhelmed by technical details bloating the manuscript.

Though the interviews were meant to cover the environmental, economic, and social pillars of sustainability (Pham and Smith 2014), the primary focus of the interview questions was the biophysical environment and specifically ecologically driven understanding and practices.

The write-ups are broadly structured into sections describing various facets of the farms (Table 16).

Table 16. List of main topics and subsections typically used to organize the written farm case studies. Farmer-approved case studies can be found in 7.5 Appendix E: Farm Case Studies.

Main Section	Subsection	Additional Description
Background		brief farmer history
History		history of the area
Environment		general description including area climate and soils
	Issues	
	Neighbors	typical nearby farming systems
Markets and Marketing System		
Farm*		specific description of farm characteristics
	crops	
	pastures	
	livestock	cattle, pigs, poultry, sheep, etc.
Infrastructure and Equipment		
Inputs and Labor		
Yields and Relative Importance of Enterprises		
Natural Environment		
	Pests	
	Biodiversity	
	Benefits	
Risk Management		
Advantages and Challenges		describing benefits and drawbacks of the farming approach
Motivation and Concerns		
Learning		
	sources	
	interesting ideas	
	future interest	
Additional Topics		

* descriptions of the productive farm elements typically involve the 'details' of that system including feed, rotation, etc. but are not always fully described (see 4.2.5 Actual Methodology)

4.2.7 Farm Anonymization

Presenting detailed information about the farms may carry some risks for the participants (see 7.1 Appendix A) and participating farmers were given the option of including their case study with the thesis, including an anonymized case study (i.e. removing names, locations, and identifying features), or not having their case study included. In order to minimize the risk of identification for those farmers that opted to have their case studies anonymized, the participating farms were randomly assigned a letter which is used through the results summary and discussion.

4.2.8 Reduction

Though presenting the collected information in an 'unreduced' form is very important, the reduction process is necessary to allow for the comparison of farming systems, creation of models, and decision making (Giampietro 2004). Unfortunately, the capacity of the information for statistical analysis is severely limited due to the low sample size of the study group (and indeed the population size) as well as the subjectivity involved in making the reduction (Giampietro 2004). This challenge to reproducibility is counterbalanced by the lower likelihood of misunderstanding or lying about the answers on a survey (Alvarez et al. 2014). Therefore the results of these reductions can only be considered suggestive and best used to generate future hypotheses.

For the purposes of this project, the information gathered in the case studies was reduced to facilitate discussion of trends and practices. The first reduction of the data is meant to summarize basic information about the farms and farmers, including a very brief characterization of the environment, demographics, and economic considerations. This was to provide give the reader a sense of the extent of the variety captured by the case studies across multiple dimensions as well as allow for observations of similarities or differences in characteristics that do not pertain directly to productive or farmscaping practices.

A second reduction was performed to summarize the farming systems themselves, describing the underlying approaches and related practices at three levels of plant ecological succession (ruderal, herbaceous perennial, and woody perennial). It also deals with management of areas that do not contribute directly to economic output (labeled as 'farmscaping' here for convenience). These areas are labeled with the understanding that in many cases management of shelterbelts or 'bush areas' may not reflect the definition of Bugg et al. (1998), who define farmscaping as "the modification of agricultural settings, including management of cover crops, field margins, hedgerows, windbreaks, and specific vegetation growing along roadsides, catchments, watercourses, and adjoining wildlands."

In principle this reduction should help suggest the existence of distinct farm types that approach the problem of ecological farming with different associated strategies, helping to answer the question 'what does ecological farming look like on the Canadian Prairies?'. With a large enough sample size, it seems possible that this information could also be useful for statistical typological analysis (e.g. principle component analysis).

Similar to the approach of Lovell et al (2010), who measured the area occupied by on-farm landscape elements to help evaluate a variety of farm components, farms were categorized using the acreage devoted to a particular successional stage. Excluding 'farmscaped' areas, the percentage of land devoted to each successional stage was recorded and used to place the farms along the gradient shown in Figure 1. Farm placement along the gradient was not mathematically exact although ordering of farms was correct, to simply be suggestive for the purposes of discussion.

Finally, yields reported by the farms were aggregated, being reported either as a percentage of conventional yields for annual crops and/or in terms of forage biomass when it was recorded or tracked. Soil types were also included to help the reader characterize limitations to production.

As a note, pursuing a numerically-based evaluation is an attractive strategy for the purposes of reduction and comparison. A numerically-based evaluation was tested for the present project, based largely on the approach of Thiessen Martens et al. (2013) and similar to Lovell et al. (2010), but was not pursued due to a number of issues:

i) the necessity of subjectively ascribing relative ecological benefits to successional stages and practices that have not been well studied or compared
ii) dealing with the potential overvaluation of approaches that involve larger numbers of beneficial practices (e.g. applying tillage reduction, cover crops, and composted manure to a ruderal system may appear better than a highly biodiverse orchard system that experiences little intervention)
iii) ascribing uniform values to certain practices where the same concept varies greatly in practice and environmental impact (e.g. tillage reduction strategies could range from the substitution of clipping for one cultivation pass to a Conservation Agriculture no-till system)
iv) dealing with the environmental contribution of landscape elements which are beneficial but are not intentional (e.g. wetland areas not suitable for cultivation). Because the opportunity cost

of these areas are very low, it seems questionable to equate them to situations where, for example, wetland areas are promoted and restored.

4.2.9 Project Biases

Available time is a resource that is normally in short supply for all types of farmers, including ecological farmers. There is a fairly high probability that the time commitment associated with participating in the project resulted in a bias against farming systems that use approaches that are more labor intensive. Examples would include regular attendance at farmers' markets and market gardening. Observationally, time seemed to be less available for younger farmers still in the process of establishing their system. Older farmers associated with Holistic Management seemed to have more time for reflection and conversation as a rule.

The project also likely selected against farms that do not use ethical labor practices. The increased labor associated with small and medium scale ecological farms, including organic farms and market gardens may sometimes result in questionable labor practices (Ekers and Levkoe 2016). It is unlikely that such farms would wish to participate in a whole farm case-study project, which possibly resulted in biasing the project towards certain types of ecological farm.

Though the project was meant to be as geographically diverse as possible within the Prairie region, most of the participating farms were concentrated in southwestern Manitoba and central Alberta. The most notable absences were central Saskatchewan and the brown soil zone of southern Alberta and southwestern Saskatchewan. Given the design of the project it is impossible to say whether this is due to less ecological farming activity or the isolation of these farmers from the organic and ecological farming communities in those areas.

4.3 Results Summary

4.3.1 Demographics

Table 17 summarizes some of the environmental and demographic characteristics of the participants and their farms. Categories were selected in order to make broad, preliminary comparisons, to present a more manageable characterization than the case studies, and serve as a reference for the discussion and analysis. The reader should note that the selection of categories is inherently subjective and that many alternative comparisons can potentially be made.

Table 17. Detail summary of selected farmer demographics, economic considerations, and farm environment characterization. The table is split in two for formatting purposes.

	A	B	C	D	E
Area Farmed (ha)	129	30	324	109	2023
Climate (relative to Prairie climate)	normal	wet	normal	normal	windy
Topography	moderate slope	flat	moderate sand hills	significant slope	gently rolling
Soil	clay and gravel	organic	sand with low loam	black loam	clay loam
Main Environmental Issue	none	flooding	oil and gas	spray drift/oil and gas	none
Farming Background[a]	no	no	yes	yes	yes
Main limitation	time	time	time	time	labor/time
People working	2	1	3	3	2+part time
Hours/day/main person (summer/winter)	14/7	n/a[b]	8	12/2	14/8
Labor programs/Internships/ Partnerships	1	0	1	0[c]	0
Off-farm work for main person?	no	n/a	yes	yes	no
Main Marketing Strategies	direct	direct	direct	direct	conventional

	F	G	H	I	J
Area Farmed (ha)	194	194	324	906	162
Climate (relative to Prairie climate)	cold and dry	windy	dry	windy	normal
Topography	gently sloping	flat	flat	flat/flood prone	very gently sloping
Soil	gravel	black/brown loam	saline mix	sand over clay	black soil zone
Main Environmental Issue	agricultural runoff	no	drought/oil and gas	agricultural runoff	urban proximity
Farming Background	yes	yes	yes	yes	no
Main limitation	Climate/Soil	Personal motivation/energy	Personal motivation/energy		Processing
People working	2	2.5	1	2	1.5
Hours/day/main person (summer/winter)	6	10[d]	10/2	9/4	10/5
Labor programs/Internships/ Partnerships	0	0	0	0	1
Off-farm work for main person?	yes	yes	no	no	no
Main Marketing Strategies	organic/direct	organic	direct	organic	direct

[a]Refers to whether the participants were raised on a farm
[b]Although the development of Farm B involves a considerable amount of work, typical hours are not included as significant income is not yet derived from the farm.
[c]Farmer plans to start internships in the near future.
[d]Farmer is currently retired.

4.3.2 Farm System Summaries

Tables 18-22 below describe the farm system approaches of each farm, the distribution of productive land maintained at a particular successional stage or 'undeveloped'/farmscaped land, and a list of ecologically relevant practices associated with each category that sometimes include experiments or ideas for the future. Although similar, the presentation of the information in the tables is not completely uniform, reflecting the diversity found within the case studies and of the farms themselves. Like Table 17 these are meant to reduce the information of the case studies and present them in a more manageable format conducive to discussion and analysis. Again, deciding what is relevant is inherently subjective, and should be read critically. The farms are not presented alphabetically in order to facilitate formatting.

Table 18. Farm system summaries that include distribution of land among successional stages, and describe agricultural approaches, specific practices, and farm features for farms B and I.

Farm B	30 ha	% of total area	Farm I	890 ha	% of total area
Developed	12 ha	41.1%	Ruderal	486 ha	54.5%
Productive Woody Perennial Land		15%	Base system	Certified organic grain	
Roads/Potential forage		5%		3 year + rotation	
Water		10%		intercrop (peas, mustard, [barley])	
				perennial forage rotated every 4, 5 years	
Plant Design				harrow, rod weeder	
	very diverse polyculture including annuals and perennials			2 cultivations if weed pressure heavy, 2 after crop off	
	microclimate (slope aspect)			5 species cover crop	
	microenvironment (slope position)			winter swath grazing cover crops	
Animals				weeds sometimes cut, baled	
	slow rotation sheep				
	seasonal pigs		Livestock (pasture & hay)	324 ha	36.4%
	chickens pastured; called back at night with feed		Base system	moderate rate rotational	
	ducks for pest control - similar management to chickens			4 species	
Farmscaping				manure from feed areas spread onto cover crop	
	berms for slowing water			moved 7 to 10 days	
	series of planned ponds and channels				
	designed wetland		Farmscaping	81 ha	9.1%
	food producing polyculture for soil stabilization			baled cattails for feed and fertility	
	planned future microclimates				

Table 19. Farm system summaries that include distribution of land among successional stages, and describe agricultural approaches, specific practices, and farm features for farms E and H.

Farm E	2023 ha	% of total area	Farm H	324 ha	% of total area
Ruderal	809 ha	40%	Ruderal	4 ha	1.4%
Base system	No-till (conventional) with rotation		Base system	not explained in detail	
	pea/canola intercrop			7 acres wheat for chickens and pigs	
	green feed poly cover crop; C3, C4 species mixes			cover crop (7 species on 4 acres)	
	perennial forage in rotation				
	C4 cover crop: stockpiled		Mixed/Livestock	259 ha in tame and native pasture	79.8%
	C3 cover crop: baled, grazed in late summer		Base system	High stock density rotational grazing	
	winter corn field for grazing (70 acres)			managed for litter cover and natural reseeding	
	winter annuals to avoid seeding on wet ground			current 4 species (soon 16)	
				Daily movement	
Pasture/Livestock	1093 ha	54%		encourage visits to low fertility areas	
	7 species seeded			bale graze/stockpile graze	
	mob grazing		Other livestock		
	stockpile grazing supplemented with bales in winter		Base system	Tractored enclosures	
				Poultry tractors moved daily across landscape (water gravity fed via truck)	
Inorganic				Pork tractor moved twice daily	
	fusarium spray			confinement partially for predators	
	some fertilizer and herbicide		Farmscaping	61 ha	18.8%
Farmscaping	121 ha	6%		Planted trees (26 ha)	
	controlled grazing of riparian areas			240 birdhouses	
	Cattle fenced out of water			Wetlands (35 ha)	
Ideas				Sloughs encouraged and fenced	
	more intercrops			Wetland/creek riparian buffer	
	ecobuffer			creek trees meant to move water upland	
	milk spreading			saskatoons, strawberries, raspberries, mushrooms, gooseberries, currants, cranberry	
	relay crop			ecobuffer experiment on farm	

Table 20. Farm system summaries that include distribution of land among successional stages, and describe agricultural approaches, specific practices, and farm features for farms J and G.

Farm J	154 ha	% of total area	Farm G	194 ha	% of total area
Livestock	146 ha	94.7%	Ruderal	162 ha	83.3%
Base system	High stock density rotational grazing		Base System	Organic management, tillage as main weed control	
	7 grass species in pasture			heavily divided fields (8x30 acres)	
	removal and growth closely monitored for plant health and soil cover			four crop rotation with two legumes	
	ultrahigh stock density, batt-latches for multiple moves per day			interrow cultivation	
	bale grazing in winter		Farmscaping	32 ha	16.7%
Other Livestock	8 ha	5.3%		8 ha slough	
	sheep rotated about every 14 days for cow complementarity			24 ha shelterbelts/ecobuffer	
	pork fenced inside bush areas with free choice feed			main shelterbelt species: 3 n-fixing shrubs with 5 non-fixers	
	laying hens confined to 0.1 acres			ecobuffer with 17 species	
Farmscaping				conventional tree establishment (weed free, tillage)	
	dugouts fenced and trees planted around low/wet areas to encourage wetlands			excess firewood, berry availability	
	extensive compost pile using winter bedding and waste		Experiments		
	all feed and 90% of hay purchased			sweetclover cover crop ploughdown	
(Market garden)				numerous crops tried	
	cover crop cocktail; grazing for fertility and weed management			crop-livestock integration	

Table 21. Farm system summaries that include distribution of land among successional stages, and describe agricultural approaches, specific practices, and farm features for farms F and C.

Farm F	194 ha	% of total area	Farm C	227 ha	% of total area
Ruderal	61 ha	31.3%	Ruderal	24 ha	10.7%
Base system	organically certified, seeding annual monocrop into tilled soil		Base system	seeding into tilled soil, inorganic fertilizer applied	
	four crop rotation (spring wheat; oats)			3 crop rotation	
	2 legumes (sweet clover; pea)			2 year green feed (oat and barley), one triticale, perennial pasture	
	green manure cover crop		Mixed/Livestock	125 ha of tame and native	55.3%
	till to encourage weeds, then prepare field; cultivate twice after fall		Base system	slow rotation through large pastures	
	cut or graze to manage perennial thistle in August			green feed is swath grazed	
Mixed/Livestock	89 ha	45.8%		9 species pasture	
Base system	holistically planned rotational grazing			creek not yet fenced	
	move cattle every 3-4 days		Other livestock (in yard)		
	riparian areas fenced			pigs with access to grass pasture	
	cows kept in field close to home for predators			chickens, turkeys kept in mobile large hoop house (moved daily)	
	bale grazing on hay fields; low fertility regions			poultry confined for protection early then given acre when more mature	
	winter manure/bedding applied on field of origin			no help given calving; farrowing	
	grass condition/recovery closely monitored			feed partially sourced from local malting plant	
	hay: 2 species; pasture: 4 species		Perennial Food	8 ha	3.6%
	dogs important for proection			hazelnuts planted along countour ditches	
Other Livestock (on yard)				asparagus planted along driveway	
	chickens; pigs are humanely confined for predators			diverse tree species along driveway (2-3 acres)	
	all feed produced on farm		Conservation Easement	69 ha	30.3%
Farmscaping	45 ha	22.9%	Farmscaping		
	maintain well vegetated water ways			contour swales	
	keep beaver dam for extending aquifer, stream			using Quonset as rain-	

<table>
<tr><td rowspan="3"></td><td>duration</td><td rowspan="2"></td><td colspan="2">capture for poultry</td></tr>
<tr><td>berry, mushroom collection</td><td colspan="2">pigs for garden tillage</td></tr>
<tr><td>shelterbelts for cattle protection, bird habitat, snow capture, aerial spray buffer</td><td>Goals</td><td></td><td></td></tr>
<tr><td>Experiments</td><td></td><td rowspan="7"></td><td colspan="2">fenced waterway</td></tr>
<tr><td rowspan="6"></td><td>Hairy vetch, oilseed radish green manure (too expensive)</td><td colspan="2">beaver dam for retention</td></tr>
<tr><td>Oat-pea intercrop (maturity dates off)</td><td colspan="2">pigs sheltered in bush</td></tr>
<tr><td>Fall-rye cover crop (first time)</td><td colspan="2">greater system component interaction</td></tr>
<tr><td>More diverse rotation (crops not suitable, unreliable)</td><td colspan="2">crop additive production (compost tea)</td></tr>
<tr><td></td><td colspan="2">plant pollinator friendly species with hazels</td></tr>
</table>

Table 22. Farm system summaries that include distribution of land among successional stages, and describe agricultural approaches, specific practices, and farm features for farms D and A.

Farm D	101 ha	% of total area	Farm A	129 ha	% of total area
Ruderal	12 ha	12%	Livestock	93 ha	71.9%
Base system	organic approach		Base system	High stock density rotation grazing	
	continuous annual green feed polyculture (4 overstory species with 4 understory species)			Cattle and sheep moved once or twice per day	
	Cover crop grazing system			Portable infrastructure	
	annual/perennial mix of 10 species			guard dogs	
Perennial pasture	61 ha	60%		bale grazing	
Base system	Holistically managed rotational grazing			stockpile grazing	
	3+6 species			chicken tractors	
	managed for natural reseeding			egg mobile	
	cattle moved once or twice a day			feed from local peas and wheat	
	field conditions determine schedule				
	supplemented with some green feed and hay in winter		Farmscaping	36 ha	28.1%
	cows wintered in enclosure			pigs kept in bush	
	bale grazing on annual field			free choice local barley	
Other livestock	on yard			well established trees, old oaks	
	mix of forage and pre-digested feed				
	grazed in cover crop and green feed		Ideas	gravity fed watering system	
	chickens and pigs have access to winter cow enclosure			greater wild harvesting (too soon)	
	access to annual field and market garden			seeding with pigs, ringing for less forest damage	
Perennial Food	8 ha	8%			
	tree rows spaced to allow grazing; pollinator coverage				
	planted on contoured swales for moisture availability,soil stabilization				
	groups spaced to reduce pest migration				
	forest garden designed to create inner microclimate				
	planned sacrificial trees (e.g. Caragana) as system matures				
	heavy mulching for establishment and mowing with side-discharger later on				
Farmscaping	20 ha	20%			
	gravity-fed water system				
	natural sloughs fenced, encouraged to return to wetland				
	systemic, high volume swale system				
	exploiting hillside for particular tree crops				
	snow fences coupled with planed shelterbelts				

	birdhouses
	dugout stocked with trout
	water solar pumped to upper pond for gravity irrigation, water points
	compost produced in animal enclosure area; spread above swales, in garden
	settlement ponds enhanced along swale to filter water coming from off-property
	scythed grass for sheet mulch pre-rain for better water absorption
	hens are kept in mobile coop in low forest garden (dethatch trees)
	dogs for chicken protection
	saskatoon, mushroom, medicinal, honey collection
Ideas	
	aquaculture; wild rice; cattails
	alnoculture; agroforestry
	sheep

4.3.3 Farm Successional Spectrum

Similar to Figure 1 in section 2.4.2, the farms have been placed along a successional spectrum based on the amount of land devoted to a broad successional stage (Figure 3). In this case, the farmscaped, conservation easement, or bush areas of their farms were excluded and the ratio of 'productive' land was used as a guideline in order to give the reader a sense of where the farms focus. It should be noted that although farms C and D have a significant amount annual producing land, preference is given to the woody perennial species in terms of weighting, in part because these crop areas are producing for feed and not export. The percentages used to determine farm location along the spectrum are shown in Table 23.

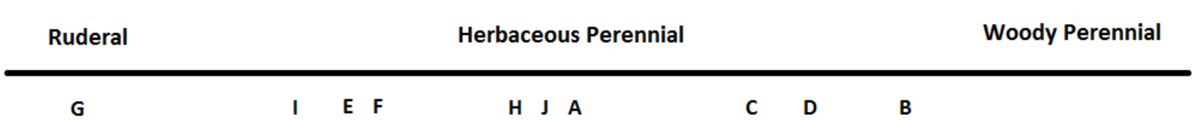

Figure 3. Visual representation of the proportion of plant successional stages of the productive areas of participating farms. Farms located between stages employ multiple approaches.

Table 23. Numerical representation of farm successional elements for the participating farms, with and without the inclusion of farmscaped land.

	A	B	C	D	E	F	G	H	I	J
	----------------------------% of Total Farm Area--------------------------------------									
Ruderal	0	0	11	12	40	31	83	1.4	55	0
Herbaceous	72	5	55	60	54	46	0	80	36	94.7
Woody	0	15	4	8	0	0	0	0	0	0
Farmscape	28	80	30	20	6	23	17	18	9	5
Percentage of Total Productive Land	72	20	70	80	94	77	83	81	91	95
	-----------------------% of Productive Farm Area------------------------------------									
Ruderal	0	0	15	15	43	41	100	2	60	0
Herbaceous	100	25	80	75	57	59	0	98	40	100
Woody	0	75	5	10	0	0	0	0	0	0

4.3.4 Yields

While yields are extremely important in the evaluation of farming systems and should be a primary focus of further research in this area, they are largely not relevant to the present project where evident financial solvency (i.e. the farmers are able to continue farming) was instead used as an implied metric for inclusion in the study. Yields are difficult to compare for a project of this type because of the large heterogeneity in output types (i.e. crop species, tame pasture, native pasture) and range of environments and soil types. Table 24 is included below only to provide the reader some context of level of productivity of these systems and is not to be used as a method of gauging success. For those farms producing annual crops, yield is expressed as a percentage of local conventional yields and is somewhat approximate as yield percentage varies based on specific crop (refer to yield information in Appendix D: Farm Case Studies for more detail).

Table 24. General summary by farm of estimated percentage of annual crop yields across species and estimate of forage production where applicable, characterized by predominant soil type.

Farm	Annual Crop Yields (% of area average)[a]	Estimate of Forage Production (kg/ha/yr)	Predominant Soil
A	n/a	1345-4000	Clay with Gravel
B	n/a	n/a	Organic
C	n/a	n.r.	Sand over clay
D	n/a	2200-2800	Black loam
E[b]	100%	≈5900	Clay Loam
F	60-75%	≈2500	Dark Grey Gravel
G	50%	n/a	Black and Brown Loam
H	n/a	3200[c]	Solonetzic gumbo
I	90%	≈2800	Sand over Clay
J	n/a	6250-9000	Black loam

[a] Based on farmer estimates of area yields, averaged across multiple crops
[b] Farm still applies fertilizer and herbicide
[c] Hay yield from one year. Normally not quantified.

4.4 Discussion

4.4.1 Farm Distribution Across Successional Spectrum

By and large, the Prairie farms participating in the case study covered the distribution between ruderal and woody perennial successional stages as their main form of production. Only one farm (G) used annual crops as their only source of income, with three more (E, F, I) having a more traditional farm approach with mixed crops and livestock. Three of the farms (A, H, J) are firmly associated with herbaceous perennials, exporting exclusively animal protein (meat and eggs), while the remaining three are pursuing woody perennial production (B, C, D) but are dependent on various animal species for the economic and environmental functioning of the system. These farms maintain a significant amount of their acreage as herbaceous perennial, more so for C and D, which depend on the farm for a significant portion of their income.

4.4.1.1Ruderal

The only farm in this study that was completely oriented towards annual production was farm G. The main reason for inclusion in the study was because of the extensive and well-established shelterbelts and ecobuffers on the farm but the combination of the farmer's commitment to improving the land within constraints provides some interesting observations within the context of the project. A potentially important observation about the farm is that it seemed to be relatively isolated (compared to the other farms) in terms of exposure to research, both University and within the ecological farming community (e.g. Acres USA magazine) - that on-farm experiments had been performed with more ecological practices was quite impressive. The interview suggested that some of beneficial practices within annual systems, including cover cropping (taking fields out of production) and crop-livestock integration (complexity of system management or challenge of making arrangements with neighbors), can be difficult to continue pursuing even after experimentation.

Two somewhat concerning strategies were looking towards an even more aggressive tillage regime and including summer fallow in the rotation in order to better manage perennial weeds, which were the largest impediment to the system's productivity. This direction may have implications for farmers switching to organic practices without sufficient educational support. One very interesting aspect of the crop system on farm G was a progressive inter-row cultivation approach using equipment designed and built on the farm. Inter-row cultivation using harrows was also practiced on farm I.

4.4.1.2 Mixed Farms

Farms E, F, and I are best described as mixed farms, with almost all of their production coming from annual crops and livestock. Though their productive area shares a mixture of ruderal and herbaceous perennial features, two are organically certified and one is 'conventional', there is a wide range in the length of time they have been farming, and they span a large size range (194, 890, and 2023 ha respectively). Despite these differences, all three are self-sufficient in terms of feed, include a cover crop or green manure in their rotation, and have some form of on-field winter grazing either through bale grazing on hayed fields (F), swath grazing cover crops (I), or a combination of stockpile grazing a C4 cover crop polyculture, corn, and native pasture (E). Both farms E and I plan for perennial forage to be a part of their long-term rotation, and the apparent lack of this feature on farm F is likely related to the poor quality of their soil on a small area that makes rotating their only crop producing areas out of annual production impractical. Furthermore, the cost of seed and a more challenging climate appear to play a role in reducing the diversity in farm F's cover crops. For grazing, Holistic Grazing Management plays a central role for farms E and F, where both employ mob grazing principles although farm F has adopted a slower rotational cycle (moving every 3 or 4 days) to balance the ecological benefits with their lifestyle preference. Farm I, though still rotating cattle regularly (every 7 to 10 days), expressed a preference for crop management which likely has affected the management of the system in a similar way as farm F.

The system for farm E, the only farm in the study that applies pest control chemicals, is patterned largely after Gabe Brown's approach (see 2.4.6 Influential Individuals) to ecological farming which combines Holistic Grazing Management principles with high diversity cover crop polycultures to maintain and enhance environmental parameters. It should be noted that farm I is also interested in learning how to approximate this model through an organic system in addition to farms A and J though they only produce livestock. Like Gabe Brown, farm E has observed a number of benefits to the system including greater levels of soil organic matter, infiltration, and water holding capacity, improved animal health, better pasture production (particularly native pasture), and improved biodiversity. However, the farm is also unique in that it has the greatest amount of infrastructure and area which raises the question of whether this system could be replicated on a smaller scale.

4.4.1.3 Annual components on non-ruderal farms

Although the farms can generally be discussed in terms of their orientation towards a particular successional stage, several (C, D, H) that are primarily herbaceous or woody perennial still are incorporating a relatively small amount of land for annual grain production. The purpose of the grain is to increase self-sufficiency by growing feed for their non-ruminant livestock. Interestingly, even though grain farming is not their specialty, these farms are still employing environmentally positive techniques including rotation including perennial forage (C), intercropping (C), polyculture (D, H), and a significant degree of crop-livestock integration (C, D, H). This is likely made possible in large part because of the livestock focus, which avoids some of the problems associated with cleaning seed and timing harvests. It should be noted that these farms are still not necessarily entirely self-sufficient in terms of feed production. Farms A and J (and B), also with a perennial focus, purchase most of their hay and feed. While farm J seeds and grazes a cover crop on a partner's market garden, there are a number of factors in common that likely keep these farms from growing annual crops: all of the farmers do not come from a farming background (Table 17), they intentionally minimize their level of equipment, A and J have arrangements with landowners that share a Holistic Grazing Management approach, and they all have a very strong commitment to the health of the soil (which also could be said for almost all of the participants as well).

4.4.1.4 Livestock and Herbaceous Perennials

A notable feature of many of the farms with livestock is that they generally contain more than one species (A, B, C, D, F, H, J), including chickens for meat and/or eggs (A, B, C, D, F, H, J), pigs (A, B, C, D, F, H, J), sheep (A, B, J), and other species for personal use (e.g. geese, ducks, goats, dairy cow) (A, C, D, J). Keeping multiple species in this way may in some circumstances be related to traditional farm practices (F), but many (A, C, D, H, J) appear to follow an approach similar to Joel Salatin (see 2.4.6 Influential Individuals). Elements popularized by Salatin including chicken tractors (A, C, H), egg mobiles (A, D), and leader-follower systems (A, J) are in evidence across these farms.

Without exception, all of the farms operating at a herbaceous perennial stage were strongly influenced by Holistic Grazing Management (A, H, J). In fact, only farms B, D, and G (residing at opposite ends of the successional spectrum) did not mention it during the interviews, although they are likely aware of it - particularly farm D which employs high stock density rotational grazing. Demographically, this group was unique in that A and J do not have a farming background and are earlier in their careers, while farm H is near retirement. All of these farms have very low levels of infrastructure and equipment, except for portable electric fence which is used extensively, mainly for high intensity mob grazing. Because both of the younger farms rent their land and have had difficulty with land tenure (both have moved more than once in the last 5 years), keeping a small amount of portable infrastructure is very important.

An important feature of farms A, H, and J in addition to C is that they all derive a significant portion of their income from non-cattle sources. Cattle provide around 70% of the farm income for both C and J with pork and poultry products accounting for 30% (this being comparable to farm F) while cattle revenues are 10% or less for farms A and J, due largely to the fact that both are currently investing in growing their herd.

Of the four farms, three use chicken tractors. As a rule the poultry are kept in groups on grass under cages that are partially sheltered and moved daily to distribute nutrients and keep a clean environment. Farm C differs from the others in that it has one large enclosure housing both turkeys and chickens compared to several smaller ones. A further difference is that as the poultry ages and becomes less prone to bird predation, they are allowed up to 0.4 ha of enclosed pasture access. Such an approach may not be applicable in all environments, considering that farm J has had some trouble protecting their poultry from terrestrial predators. All of the farms raising poultry for meat (excluding B and D), use the Cornish Cross breed. Though this is not ideal for the farmers, who would prefer a hardier variety more adapted to foraging, the extremely fast growth rate compared to the other varieties makes them the most economical option.

All four farms have an unconventional approach to pork production, either via pig-tractor which is very similar to the chicken tractor concept (H) or keeping them in the bush areas (A, J, and high priority for C). The farmers are fairly happy with both approaches and proud of the meat quality that they produce. Even though their feed is always free choice, farms A and J have both remarked that the pigs consume a significant amount of forage although there are some apparent differences in management strategy in terms of rotation rates and vegetation protection (though this may be related to lack of detailed discussion in the interview). These approaches are in line with research documenting a resurgence in interest for raising pork in an outdoor environment and the contribution of forage consumption to their diet (Rodríguez-Estévez et al. 2009; Kanga et al. 2012).

Furthermore, A and J were the only farms raising sheep as a significant portion of their income. Both pursue a similar mob-grazing approach in order to complement the forage use of the cattle as well as interrupt disease cycles.

The intensive management of multi-species on the primarily herbaceous perennial systems (A, C, H, J) contrasts with the presence of only cattle on mixed farms E and I. While farm F derives a significant amount of their income from poultry and pork, their management system appears to be more traditional (i.e. the animals are kept in and around the barn).

4.4.1.5 Mixed mid and later-succession

In terms of successional stage, farm C is an interesting case because in many respects it forms a bridge between the herbaceous and woody perennials. While its present and future farm income streams are animal protein-based, it is deeply informed by various Permaculture-related sources and is attempting to apply both social and biophysical principles associated with it. In their case the productive vegetation includes a number of fruit trees and asparagus along roadways and extensive hazelnut planting (both of which are still very new) and they have added some water harvesting swales as well. Farm C is also strongly influenced by Holistic Grazing Management, likely in part because of their background, which to-date appears to have driven their decision making process more than organized their grazing management, making an interesting comparison with the other farms oriented towards herbaceous perennials. Still, they share with the other mid-succession farms a pastured poultry approach and are attempting to develop a system for raising their pork in forested areas.

Where farm C contrasts mainly with the late succession farms (B, D) is in the intensiveness of the planning and the extent of productive woody perennials in terms of land area. For example, farms B and D have detailed maps of their property where all parts of the managed property are intensively planned, especially in terms of water control and tree planting. While farm C is aware of and is including these elements, they appeared at the time of the study to be more ad hoc. However, given the enthusiasm of farm C for woody perennial production systems and Permaculture, this is very likely to be as a result of the time and energy costs associated with producing a large portion of their income from the farm as well as working off farm. Increasing their self-sufficiency in terms of feed by including ruderal elements (green feed, triticale, cover crops) adds another layer of management and planning. Because of these constraints, which are less pressing for farms B and D, the future development of this system may be of most interest for those looking to transition towards systematic inclusion of woody perennial species.

4.4.1.6 Later Successional Farms

Unsurprisingly, the two farms (D, B) with the greatest orientation towards woody perennial growth are primarily influenced by the Permaculture literature. It is necessary to point out that neither of these farms currently derive a significant portion of their income from this part of the farm (off-farm work for B, off farm-work and herbaceous perennials for D). Furthermore, while both woody perennial systems are quite new for both farms, D is somewhat more established.

One of the important underlying features that both farms share is a systematic approach to water management, where water flow over the farm is well understood, directed, and controlled in such a way as to maximize the benefit to the farm. For farm D, this involves capturing and storing as much as possible through the use of swales and ponds, while farm B has created a series of berms, channels, and a wetland to deal with a large amount of excess water and improving formerly unproductive land. Both farms are now seriously considering an aquaculture enterprise as a result.

The farms also base their planting on microclimates, planned or existent, where in general hardier trees are planted to face and create shelter for more susceptible species. On farm D, the tree spacing is dense to allow for the inclusion of sacrificial, typically N-fixing species that can be chopped or ultimately removed but help with soil fertility and establishment, which is similar to an approach that has been shown to be beneficial in annual cropping systems (Wiens et al. 2006). Diverse species and varieties are also planted on both farms, partly to determine what succeeds in the environment and partly to reduce the risk of pest outbreak.

Finally, both farms include multiple species of livestock: cattle, pigs, and chickens on farm D and sheep, pigs, and chickens on farm B. The management system is extensively planned out on farm D, attempting to create beneficial connections between as many of the farm elements as possible while minimizing the amount of management effort. This is done particularly by using the zone concept (Holmgren 2002; Hemenway 2009) which is the planned spatial distribution of areas requiring frequent tasks in convenient locations, often near a dwelling, and less common tasks further away. Here, cattle management follows the Holistic Grazing Management pattern, an egg-mobile is used, but differs from the herbaceous perennial farms in that the pigs are more integrated with an annual cover crop polyculture than rotated spatially. The approach of farm B is less intensive (e.g. sheep are rotated through 4 pastures), largely due to of lifestyle requirements, but has had success in raising free-ranging poultry by putting them on pasture during the day and protecting them at night with electronet fencing. It is very likely that as the woody perennials continue to mature, livestock will be integrated in a silvopasture arrangement, while laying hens are already being used in this way on farm D.

One of the more notable features of Permaculture is its emphasis on forming connections between elements. This feature was most obvious for farms C and D (it may simply be less apparent on B because of its stage of development) where attempts are being made to form synergistic relationships between features of the farm, with the end results including greater productivity, lower pest pressure, and lower labor costs. This can be evident in large ways (e.g. the interaction of pigs, cows, and chickens in the wintering enclosure or the dethatching behavior of laying hens on farm D), or smaller synergies (e.g. passively collecting rainwater from a quonset for poultry on farm C). This approach is almost formalized in the leader-follower systems of the herbaceous perennial group of farms, which makes it difficult to say how large a role explicitly searching for these connections plays in their formation and indicates that its role is mainly in improving adaptation to local conditions. In terms of Permaculture language, this process would take place through the principle of "Observe and Interact" (Holmgren 2002) and farm C has described it as a process of 'togethering'. Given the demands of general farm operation, particularly for the relatively high diversity of these ecological farms, it may be that such an approach needs to be formalized in order to maximize its benefit.

4.4.2 Farmscaping and Non-Productive Areas

Similarly to using successional stage as a scale for conceptualizing ecological farms, the approach to areas not directly contributing to farm production can be thought of as moving from conceptualizing them as unproductive, natural areas to protecting existing features to promoting and creating more features on farm. A second dimension is the type of feature involved, normally either water (e.g., wetlands, streams) or vegetation (typically woody perennial). As a whole, the study participants were generally either conscious of protecting these areas or developing and improving them.

4.4.2.1 Water

Farms at earlier successional stages (E, F, G, I) tended to take a more passive approach; fencing out waterways and sloughs from cattle (or tightly controlling grazing in the case of E) and being relatively philosophical about excessive water reducing acreage. The herbaceous perennial farms, H and J in particular, are interested in encouraging greater wetland habitat on the property by redeveloping formerly drained or degraded areas (which has largely taken place already on farm J). This is also the case for the woody perennial farms B and D, but is difficult to separate from the intensive planning and design of their water systems.

4.4.2.2 Trees

The influence of the type of system is much less clear with respect to trees (shelterbelts, 'wasteland', ecobuffers), and may be more strongly influenced by personal views. Farm G, though fully ruderal in production, had the most extensive and developed shelterbelt and ecobuffer plantings among the farms. This was in part because of the risk of wind damaging or destroying crops, but also especially as habitat for birds and wildlife, very remarkable in a region with very few trees. Similarly, Farm H has planted an extensive number of multi-species shelterbelts largely for habitat, plantings fenced off exclusively for habitat, an ecobuffer trial, as well as placing a very high value on the forested areas. Both farms D and H are interested in strips of beneficial insect habitat placed close enough so that pollinators are able to cover the full productive areas as well. Farm C is similar in planning on planting wildflower mixes to create pollinator habitat.

For farms A and J (and eventually C), forested areas are in fact productive and serve as pasture for pigs and, for farm A, cows. Though the effects of the pigs are much different than cows on pasture, they are still rotated and the quality of the environment is monitored. The only farm where the unproductive parts of the farm did not appear to be of major importance was farm I, where again tree and bush areas are not typically a part of the landscape. The treed areas for farms B, E, and F are not intensively managed but do have shelter and some forage value (E and F). They also did not express immediate plans to further develop their treed areas, likely because they are already substantial (F) and have many other more pressing projects (B, E).

As a final observation, many of the farms get direct benefits from their treed areas, including firewood, berries, mushrooms, and medicinal plants (B, D, F, G, H) which are sometimes quite substantial. Other farms (A, B, J) expect to take more advantage of the natural areas as they spend more time on their properties.

4.4.3 Economic and Environmental Sustainability

4.4.3.1 Risk Management

The dominant form of risk management practiced by the vast majority of the farms was through diversity. This included diversity in marketing strategies, management strategies, on-farm elements, and multiple sources of income.

Overall, there were no overriding trends in terms of biophysical risk management. In most cases the farming systems were too new (A, B, C, D, E, J) to have experienced any major droughts or other disasters and, though cautiously optimistic, did not have explicit strategies beyond the environmental advantages of the system itself. However, the approach of the more experienced small-scale farmers is to remain flexible and prepared for adverse conditions. Farm

H has experienced significant drought in the past and intentionally keeps their herd of cattle lower than the carrying capacity, opting instead to custom graze which allows them the flexibility to destock rapidly if necessary. Similarly, Farm F likes having the option to sell calves instead of yearlings, or being able to process cull cows locally or at a larger facility. Farm F also keeps enough seed to replant in the case of total crop failure. Both Farm F and H see their riparian areas and sloughs as insurance against extended droughts as well.

Diversification of income streams is the most common form of risk management. Of the four farms that produce annual crops, three are mixed farms with at least two streams of income. Farms concentrating in animal products typically sell poultry, pork, and beef (mutton in two cases). In many cases there are further species raised for personal use (e.g. rabbits, goats, dairy cow, geese, ducks). This diversity helps insulate the farmers both from a disaster specific to a species (e.g. parasite infection) as well as from fluctuations in the market. Many of the newer farms are considering further diversification (A, B, C, D, E, J) for these reasons as well as increased synergistic connection between the farm elements (C, D). There is also significant interest in the creation of value added products (e.g. jams and jellies) and ecotourism (B, C, D, E, already existing on H).

Almost all of the farms had someone engaged in off-farm work (A and E perhaps being the only exceptions) although it was often not clear whether the work was essential to the operation of the farm. Farms C, D, and G (excluding B where significant income is not derived from the farm) were the only ones where the 'main' farmer engaged in significant levels of off-farm work.

Crop or pasture insurance of some kind is also used by several of the farms (A, C, E, H, I) but typically to a limited extent. This is in part because the farm systems are not particularly conducive to insurance due to crop type or management strategy, but also because many of the participants do not have positive perceptions of the incentives that insurance gives to producers. In several instances (e.g. C, E, F) - even some with insurance - participants expressed that crop insurance skews perceptions and encourages farmers to use strategies that are riskier and less sustainable (economically and environmentally) than otherwise.

4.4.3.2 Marketing and Processing

For many of the participants marketing strategy is an important part of their risk management. This is the most true for the farmers that market their products directly and through CSA models (A, B, C, D, F, H, J). By explaining their farming practices to and forming individual relationships with their customers, they are able to create a level of trust that keeps more business and maintains prices in the event of market fluctuations or crises (McLachlan and Yestrau 2009). Additionally, this approach is congruent with many participants' goal to produce food for people. Farm D has developed a forest garden CSA as an alternative to a bank loan through relationships created with the local community, with products delivered to the customers as a percentage of their investment over several years (changing and increasing over time).

The main limitation associated with pursuing direct marketing is the time, effort, and inclination required to develop and pursue those relationships. In most cases creating and maintaining a website is an important part of their marketing strategy (A, B, C, D, H, J), in addition to creating videos and holding farm tours (B, D, H). However, Farm F indicated that once they are formed they require significantly less energy to maintain. Somewhat surprising was the fact that almost none of the participants use farmers' markets on a regular basis (H).

Even those that attend use them minimally, primarily as a method of attracting new customers and sometimes selling excess product. Although those that discussed farmers' markets felt that they could make more money through them, time and effort are again the limiting factors.

Similarly the distance from larger centres is another limitation. Many of those farmers pursuing direct marketing find the majority of their customers in cities, which creates increasing cost with increasing distance as the participants typically bring their products into the centres. This is attenuated with the use of regular delivery schedules and drop-off points that make transportation more efficient, but several farmers have turned down customers because of the inconvenience of distance. For those that live a greater distance away, the price of fuel quickly becomes an important consideration as well as the time commitment.

Two major concerns for the farmers that direct market are the availability of abattoirs and meat processors and government regulation (A, C, D, H, J). They have observed that most of the processors, like farmers, are old and there are very few people taking over as they retire (H,J). The farmers see this trend as a combination of more attractive wages and lifestyles in other industries as well as increased centralization of processing facilities. The problem for ecological farmers is that their small scale makes it uneconomical for them or the large processors to deal with their animals, and they rely on maintaining good relationships with local processors in order to create attractive products. For farm H the lack of processor options means having to forgo organic certification. The lack of provincially inspected chicken facilities in particular is a significant challenge for many of the farmers.

Much of the marketing takes place through certain groups. This is sometimes through direct marketing via family (e.g. E, F) and organic markets (G, I), but is also through urban

Permaculture connections (C, D) as well as the Weston A. Price group (C, E). Though most of the HM farmers that mainly direct market do not feel that organic certification is essential (or necessarily beneficial), it remains very important to satisfy their customers - notably avoiding soy-based feed for Weston A. Price customers.

4.4.3.3 Environmental Performance

Environmentally, the participants were all generally content with their levels of biodiversity and environmental performance. As there was no baseline in most cases, it is impossible to say that biodiversity is greater compared to other farms especially in instances (A, B, F), where it may be due to operation in a more marginal, less developed environment. Furthermore, the age of many of the farm systems (A, B, C, D, E, J) make it too early to draw strong conclusions in this area given time scale often associated with environmental sustainability (Glover et al. 2010).

With that said, bird populations and diversity were the most prominent indicators of environmental performance for some of the farms, particularly for the older systems G and H. Farm G, where a study reportedly identified 60 bird species nesting in the shelterbelts, told a story of how 15 years after switching to organic, he and his father saw a Baltimore Oriole and a goldfinch on the farm which his father hadn't seen since he was a little boy. Meadowlarks disappeared from Farm H in 1989 but returned in 2001 after changing the approach in 1995. Farm H now has had 93 species of bird documented on their farm through university surveys and Farm G estimates that they have around 100 species (though not verified). Farm I did not discuss the environmental effects of transitioning to organic production in great detail, but has observed an increase in birds in addition to beneficial insects like dung beetles and pollinators. Measuring environmental performance was also not a focus for Farm F, but the return of meadowlarks after several years absence, the abundance of frogs, and the direct benefits they gain from uncropped areas (e.g. mushrooms, cranberries) suggests that their system would likely compare favorably with representative conventional farms.

Though soil health tended not to be discussed in general, almost all farms had strategies to protect or improve it using strategies associated with their respective successional stage. The mixed farms tended towards cover crops (E, F, I) and including perennial forage in rotation (E, I), those with herbaceous perennials closely monitor their usage to leave good ground cover (A, E, F, H, J) and use winter feeding strategies to distribute nutrients (A, C, D, E, F, H, I, J), and farm D (B is not quite at this stage) mulches extensively in addition to the water system in order to build soil as much as possible to enhance the health and growth rate of the planted trees and shrubs. The most common soil health indicator species for many of the farmers were dung beetles (A, D, I).

Plant health and animal health was universally almost a non-issue, with only minor problems (lice and foot rot) sometimes affecting cattle. Some of the participants are interested in or monitor their grass health with a Brix meter for sugar content (A, E, J), and have reported increases with changes in management.

4.4.4 Personal and Social Characteristics

In retrospect, the demographics and personal characteristics were the least well documented, yet an important aspect of the study. Simple details such as age or education level were not explicitly incorporated into the questionnaire, which may have been beneficial in interpreting the trends. This section is therefore more subjective than the others, depending on observation as well as farmer-approved information.

Though age was not explicitly recorded, the participants largely are split between newer (A, B, C, D, E, J), well established (I), and late career (F, G, H). The education level of the farmers ranged between high school and Master's degrees, but this did not appear to have any bearing on the farming systems. All of the participants read and experiment extensively, and appear to be quite adept at managing the farms in ways that functions within the current social and economic paradigm while maintaining their ideals.

Aversion to debt was a theme that was either implicit or explicit for several of the farms. Being debt free was mentioned especially by the older farms (F, G, H) and escaping an overwhelming debt load was one of the motivations for pursuing ecological agriculture (Holistic Management) for farm H. Though more implicit, the farms without a farming background (A, J) are also financially cautious - slowly building their herds and businesses, renting land, and not making any one large capital investments. By contrast, farm D is experimenting with small community based loans in order to fund longer term capital generating projects (e.g. forest gardens).

Additionally, the ethics of farming were an important dimension for many of the farmers. Those farms that do not sell into commodity markets often expressed the importance of producing food for people (A, C, D, H, J) and all of the farms highly valued maintaining a healthy environment. Independence was another theme expressed in a number of ways, including debt avoidance and financial freedom (above), but also in being willing to be unique (best exemplified by farm G), being able to make their own agronomic decisions (I), and an entrepreneurial willingness to create and develop their own markets (A, B, C, D, F, H, J).

A large concern for most of the farms that direct market animal proteins is the precarious state of local abattoirs and butcher shops (A, C, D, H, J). These farms rely on local processors that evidently mirror the farmer demographics in that they are largely old and retiring. Governmental policy favoring large-scale operations that only deal with large volumes make it difficult for the smaller businesses to comply with regulations and result in fewer options for small-scale farms (especially for chicken processing). As a result several of the farms are looking into other options such as community-based mobile abattoirs (C, D, J).

4.4.5 Research Avenues

4.4.5.1 Biophysical and Societal Evaluation

The most obvious line of research is in a large range of biophysical comparisons to quantitatively evaluate the impacts of the farms on the ecosystem, including soil parameters, water and nutrient cycling, and macrofauna, among others. These comparisons would be useful to make against representative regional farms as well as ecosystems, and also between types of farms using different systems and at different successional stages. One of the most interesting comparisons would be between the environmental, economic, and energetic performance of a "Gabe Brown" approach that uses minimal chemical, avoids tillage, and extensively integrates crops and livestock (e.g. E) on a mixed organic farm (e.g. I).

A further avenue would be to examine the relative health of crops and livestock. The most prevalent disease among the farms was foot rot among cattle, which was almost always associated with unfenced water areas. The experience of an epidemic of disease among cattle on farm E when transitioning onto formerly sprayed and monocropped crop areas may also be worth exploring.

Yield and energy analysis are likely the most pressing questions raised by the systems in terms of implications for wider society, and might well be addressed by modeling or typological approaches (Le Gal et al. 2011; Alvarez et al. 2014). The design and operation of the farms at later successional stages seems to indicate that the amount of energy produced from that invested is quite favorable considering their minimalist use of equipment and intervention generally, especially when taking into account the institutions beyond the farmgate and social complexity necessary to sustain more conventional/ruderal approaches (Murphy and Hall 2010). Currently, the caloric output per acre of these systems is likely to be much less, especially because of their livestock orientation, which reduces their attractiveness at the societal level (Giampietro 2004). However, as perennial crops (e.g. wheat, nuts, fruit) continue to be developed and the agronomy of these systems improves, this may change substantially.

The perceptions of the farmers applying Holistic Grazing Management principles provide support for many of the productive and biophysical benefits purported by Holistic managers (Jacobo et al. 2006; Teague et al. 2011; Ferguson et al. 2013; Teague et al. 2013) even if negated by the majority of the grazing literature (Briske et al. 2008). The fairly uniform observations by the study participants of improvements in production, infiltration, and soil health generally (A, D, E, F, H, J) make this approach worth studying - taking care to account for adaptive and scale-appropriate management (Teague et al. 2013).

An open question however is what are the limits to production, particularly for mature Permaculture systems. Production from woody perennials (B and D) has not yet begun, and further enterprise such as aquaculture and mushroom cultivation seem to be viable additions to this system that supports livestock as well. Another important question is to what degree can these systems produce substitutes for staple crops such as hazelnut and pine nuts, as suggested by

Mark Shepard and the Savanna Instititute (Shepard 2013; WPP Research Site 2015). Nevertheless, the existence of such farms and their evident initial success in establishment gives evidence that Permaculture-derived woody perennial food production configurations are indeed possible in the Canadian Prairies.

4.4.5.2 Improvement

There are a large number of opportunities for researching ways of improving the farming systems themselves. Conditions associated with the different successional stages are very different from conventional farms, and it seems likely that breeding varieties that are better suited would allow for significant progress in terms of production and functioning of the systems. Fast-growing poultry bred for pasture would probably be the best example.

Given the extensive research done on organic and ruderal systems, the present project did not identify any major new innovations with regard to crop production itself. In terms of increasing environmental sustainability within these systems, further research on integrating farmscaping elements in the field margins is the neglected area with the most potential. This could be enhanced by incorporating Permaculture design and water management principles, creating productive value (food, wild products, enhanced wildlife and pollinator habitat) beyond historical ecosystem services (wind protection, snow capture) in a way that minimizes costs for the farm and lowers the likelihood of future removal.

For herbaceous perennial systems, research into different strategies of managing multiple livestock species on the same land base would complement farmer innovation, and allow for experimentation with unusual combinations, either to capture a greater amount of plant resources or to lower the risk of pests. This approach seems to lend itself as a point of entry for those without a farm background, therefore research could be performed on different strategies to begin farming at this successional stage. The different approaches to pig management (bush, tractored, cover crop/pastured, traditional) varied widely among the studied farms and investigating their relative costs and benefits would be very interesting.

For woody perennial systems, given the young age of the discipline in western Canada, looking at effective polycultures given available cultivars and different methods of system establishment would be quite valuable. Other lines of research include developing different strategies for income while the system matures, testing different methods of integrating livestock, and also testing to see what boundaries can be pushed in terms of plant hardiness (e.g. protecting certain trees from sunscald).

Another valuable area of research is developing a systematic approach to landscaping for water management, in spite of numerous papers mentioning specific strategies and approaches (Black and Reitz 1969; Sun et al. 2008; Benoît et al. 2012; Altieri et al. 2015). The woody perennial farms using this approach are both increasing water availability in a drier climate (D) or managing excess water (B) by applying the same understandings of how water interacts with landscape features. While farm D has likely succeeded in capturing much more than many other farmers would prefer, observing and planning around how water moves across the landscape and using less invasive techniques such as contour farming (Black and Reitz 1969) might have a positive result for those in drier regions especially in the face of climate change.

4.4.5.3 Economic and Social Sustainability

Economically and socially speaking, the farms appear to be performing reasonably well. One of the themes was a general aversion to debt and preference for self-sufficiency (e.g. F, H).

Holistic Grazing Management planning is a major factor for the economic decisions of many of the farms (C, F, H, J) but the effectiveness of this decision making model on farm economic sustainability does not appear to be well studied to date (Teague et al. 2013). Some farms (C, E, less explicitly with several others) mentioned that their land base is likely sufficient to support more families and enterprises due to the large potential for value-added products (e.g. preserves, honey, compost, more small livestock).

The interviews suggest that ecological approaches to food production that involve multiple streams of income, direct marketing, and a high degree of diversity have the potential to strengthen the social and economic networks in rural communities and slow or reverse the movement of people off the landscape. Integral to this are the greater prices and margins associated with community-supported and organic agriculture. There is a tension between supporting farm livelihoods that have the freedom to make positive ecological decisions and minimizing food costs, especially for the urban poor (also discussed by farm B and H). On the other hand, these ecological approaches appear likely to involve many fewer environmental externalities as well as potentially higher food quality. Furthermore, because of the local orientation of most of these systems, they likely offer a higher degree of food security and sovereignty in the case of disruptions to supply chains at higher levels of social organization. The role of research here would be in exploring the effects of different policies and prices on the prevalence and nature of a smaller-scale ecological approach and modelling their effects under different scenarios. While it is unlikely that it would be socially or economically acceptable to promote these systems as a complete replacement for ruderal agriculture, supporting them as a risk management resource in terms of their knowledge, skills, and varieties is probably inherently valuable - analogous to the diversity-based approach to risk management adopted by the farms themselves. An additional approach may be to foster this knowledge and skill-set within cities or peri-urban areas among interested individuals.

One of the expectations going into the project was that ecological farmers would have a extensive taxonomic and functional knowledge of a large number of species, particularly pest insect and plant species. However (with some exceptions), this only seemed to occur when farmers were either interested as a hobby or where it was economically relevant. This seems to be consistent with limiting the informational intensity in ecological engineering proposed by Bergen et al. (2001). Given the high degree of knowledge and skill already required to manage an ecological farm, it may be important to determine whether having knowledge at a greater level of detail is beneficial and when a general understanding is sufficient.

Nevertheless, all of the participants seemed to be either well educated or quite intelligent and shared a value of caring for the earth and often producing food for people. Determining how intelligence and ethics play into creating and maintaining these often very complex systems may also be a factor in determining how realistic expanding these types of systems might be, and whether they will maintain their ethics if the size of the industry grows.

Under these circumstances, it is likely that the most appropriate consultants for these types of farms would have a holistic appreciation for the multiple farm features but also specialize in a particular area to diagnose problems or suggest improvements. For example, a soil scientist with a good understanding of HM practices and philosophy would likely be most effective in helping HM-oriented farmers learn what is going on in their soils and how to continue to improve them.

5.0 SUMMARY AND CONCLUSIONS

Overall, the two chapters of this thesis describe a variety of agroecological approaches to food production that have the potential to contribute to agricultural sustainability. The continuing development of perennial grains offers the possibility of an entirely new agronomic system while ecologically oriented Prairie farmers are adapting and developing a diverse set of systems, novel or well-established, that promote a better relationship between humans and the environment.

A major theme that has emerged over the course of the project has been an orientation towards reducing disturbance and increasing the state of ecological succession. Most of the benefits expected from perennial grains derive from their perennial nature being a mimic of a grassland ecosystem and many of the interviewed farmers expressed an aversion to annual cultivation in order to protect their environment. Neither chapter examined the environmental benefits associated with the systems, but many of the farm interviews and tours suggested that they likely have a substantially higher level of biodiversity than conventional farm systems.

However, increasing diversity, either in the field through intercropping and polyculture, integrating crops and livestock, stacking enterprises and marketing strategies, or adding and developing landscape features, also increase the complexity of the system and makes it more challenging both to study and manage. In the case of IWG, the system dynamics could have been greatly altered by using different varieties or species of legume and research examining the inclusion of livestock in seed production systems suggests that timing, duration, species, and stocking density all play an important role in determining the subsequent crop response. This challenge is compounded by the fact that such a system is ultimately meant to last several years, increasing the possibility that stochastic events (e.g. drought, animal disturbance) reduce its predictability. This is also especially apparent for farms involving perennial species, where adaptive management is key to making the systems successful: e.g. close monitoring of grass conditions, weed species, and the effect of grazing, observing, and exploiting microclimate opportunities as very diverse tree-based systems mature in a particular landscape.

Another theme running through both chapters is the challenge of dealing with lower productive outputs (for now). In both the case of IWG and the interviewed farms, diversification of the system, whether by integrating livestock, stacking farm elements, direct marketing, or adding income streams and enterprises, appears to be the broad way of addressing this issue, in addition to helping mitigate market and environmental risk. However, managing more diverse systems requires more skills and knowledge, and some aspects of the system may suffer compared to more specialized approaches. These challenges mount as farm design becomes complex, where the farms employing the most involved plans require a large amount of time due to the need to learn about and implement their designs. Some interviews suggest that this issue may be addressed by partnering with more people, although higher revenue margins (relative to conventional markets) are a key factor in allowing these systems to develop.

6.0 LITERATURE CITED

Aamlid TS. 1993. Autumn treatment in smooth meadowgrass (Poa pratensis L.) grown for seed. Nor. landbruksforsking 7:117–138.

Abdollahi L, Munkholm LJ. 2014. Tillage System and Cover Crop Effects on Soil Quality: I. Chemical, Mechanica;, and Biological Properties. Soil Sci. Soc. Am. J. 78:262–270.

Acosta-Martinez V, Bell CW, Morris BEL, Zak J, Allen VG. 2010. Long-term soil microbial community and enzyme activity responses to an integrated cropping-livestock system in a semi-arid region. Agric. Ecosyst. Environ. 137:231–240.

Altieri M a. 1989. Agroecology: A new research and development paradigm for world agriculture. Agric. Ecosyst. Environ. 27:37–46.

Altieri M a., Nicholls CI, Henao A, Lana M a. 2015. Agroecology and the design of climate change-resilient farming systems. Agron. Sustain. Dev. 35:869–890.

Altieri MA. 2002. Agroecology: The science of natural resource management for poor farmers in marginal environments. Agric. Ecosyst. Environ. 93:1–24.

Alvarez S, Paas W, Descheemaeker K, Tittonell P, Groot JCJ. 2014. Constructing typologies, a way to deal with farm diversity: general guidelines for the Humidtropics. Report for the CGIAR Research Program on Integrated Systems for the Humid Tropics. Netherlands: Plant Sciences Group, Wageningen University.

Anderson RL. 2015. Integrating a complex rotation with no-till improves weed management in organic farming . A review. Agron. Sustain. Dev. 35:967–974.

Asay K, Jensen K. 1996. Wheatgrasses. In: Bartels J, Moser L, Buxton D, Casler M, editors. Cool-Seaseon Forage Grasses. Madison, WI: ASA, CSSA, SSA. p. 691–724.

Asay K, Knowles R. 1985. The Wheatgrasses. In: Heath M, Barnes R, Metcalfe D, editors. The Science of Grassland Agriculture. 4th ed. Amex, IA: Iowa State University Press. p. 166–176.

Avis R, Avis M. 2012. Front Page. Verge Permac. Permac. Innov. Prof. Entrep. [accessed 2016 Jun 13]. http://vergepermaculture.ca/

Barbercheck M. 2014. Brown’s Ranch: Farming in Nature's Image to Regenerate Land Productive, and Quality of Life. PennState Ext. Sustain. Agric. [accessed 2016 Jun 14]. http://extension.psu.edu/plants/sustainable/news/2014/spring/browns-ranch

Bartzen BA, Dufour KW, Clark RG, Caswell FD. 2010. Trends in agricultural impact and recovery of wetlands in prairie Canada. Ecol. Appl. 20:525–538.

Batello C, Wade L, Cox S, Pogna N, Bozzini A, Choptianv J, editors. 2013. No Title. In: Perennial Crops for Food Security: Proceedings of the FAO Expert Workshop. Rome: Food and Agriculture Organization of the United Nations.

Bausenwein U, Millard P, Raven JA. 2001. Remobilized old-leaf nitrogen predominates for spring growth in two temperate grasses. New Phytol. 152:283–290.

Beckie HJ, Sikkema PH, Soltani N, Blackshaw RE, Johnson EN. 2014. Environmental impact of glyphosate-resistant weeds in Canada. Weed Sci. 62:385–392.

Bell L, Byrne F, Ewing M, Wade L. 2008. A preliminary whole-farm economic analysis of perennial wheat in an Australian dryland farming system. Agric. Syst. 96:166–174.

Bell LW, Sparling B, Tenuta M, Entz MH. 2012. Soil profile carbon and nutrient stocks under long-term conventional and organic crop and alfalfa-crop rotations and re-established grassland. Agric. Ecosyst. Environ. 158:156–163.

Bellet L. 2009. From Cultural to Supporting Ecocystem Services, The Value of Shelterbelts to Prairie Agriculture, Canada. Royal Roads University.

Benoît M, Rizzo D, Marraccini E, Moonen AC, Galli M, Lardon S, Rapey H, Thenail C, Bonari E. 2012. Landscape agronomy: A new field for addressing agricultural landscape dynamics. Landsc. Ecol. 27:1385–1394.

Bergen S, Bolton S, Fridley J. 2001. Design principles for ecological engineering. Ecol. Eng. 18:201–210.

Black AL, Reitz LL. 1969. Row Spacing and Fertilization Influences on Forage and Seed Yields of Intermediate Wheatgrass, Russian Wildrye, and Green Needlegrass and Dryland. Agron. J. 61:801–805.

Blanco-Canqui H, Mikha MM, Presley DR, Claassen MM. 2011. Addition of Cover Crops Enhances No-Till Potential for Improving Soil Physical Properties. Soil Sci. Soc. Am. J. 75:1471–1482.

Board CGS. 2015. Organic production systems - General principles and management standards. Public Work. Gov. Serv. Canada. [accessed 2016 Jun 16]. http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/programme-program/normes-standards/internet/bio-org/pgng-gpms-eng.html

Boatwright G, Viets F. 1966. Phosphorus absorption during various growth stages of spring wheat and intermediate wheatgrass. Agron. J. 58:185–188.

Bonaudo T, Bendahan AB, Sabatier R, Ryschawy J, Bellon S, Leger F, Magda D, Tichit M. 2014. Agroecological principles for the redesign of integrated crop-livestock systems. Eur. J. Agron. 57:43–51.

Briske ADD, Derner JD, Brown JR, Fuhlendorf SD, Teague WR, Havstad KM, Ash AJ, Willms WD, Briske DD, Derner JD, et al. 2008. Rotational Grazing on Rangelands : Reconciliation of Perception and Experimental Evidence Synthesis Paper Rotational Grazing on Rangelands : Reconciliation of Perception and Experimental Evidence. Rangel. Ecol. Manag. 61:3–17.

Briske DD, Ash AJ, Derner JD, Huntsinger L. 2014. Commentary : A critical assessment of the policy endorsement for holistic management. Agric. Syst. 125:50–53.

Bronson K, Knezevic I. 2016. Big Data in food and agriculture. Big Data Soc. 3:1–5.

Brown G. 2016. Welcome to Brown's Ranch! Brown's Ranch "Regenerating Landscapes a Sustain. Futur. [accessed 2016 Jun 14]. http://brownsranch.us/

Bugg R, Anderson J, Thomsen C, Chandler J. 1998. Farmscaping in California: Managing Hedgerows, Roadside and Wetland Plantings, and Wild Plants for Biointensive Pest Management. In: Pickett C, Bugg R, editors. Enhancing Biological Control. Berkeley and Los Angeles, CA: University of California Press. p. 339–374.

Butterfield J, Bingham S, Savory A. 2006. Holistic Management Handbook: Healthy Land, Healthy Profits. Washington, DC: Island Press.

Canada E. 2016. National Climate Data and Information Archive [online]. [accessed 2016 Jul 7]. http://climate.weather.gc.ca/index_e.html

Canode C. 1964. Influence of cultural treatments on seed production of intermediate wheatgrass (Agropyron intermedium (Host) Beauv.). Agron. J. 56:207–210.

Canode C. 1968. Influence of row spacing and nitrogen fertilization on grass seed production. Agron. J. 60:263–267.

Carson R. 2002. Silent Spring. New York, NY: Houghton Mifflin Company.

Chamblee D, Collins M. 1988. Relationships with Other Species in a Mixture. In: Hanson A, Barnes D, Hill R, editors. Alfalfa and Alfalfa Improvement. Madison, WI: ASA, CSSA, SSA. p. 439–461.

Chappell MJ, LaValle LA. 2011. Food security and biodiversity: Can we have both? An agroecological analysis. Agric. Human Values 28:3–26.

Christoffoleti P, Galli A, Carvalho S, Moreira M, Nicolai M, Foloni L, Martins B, Ribeiro D. 2008. Glyphosate sustainability in South American cropping systems. Pest Manag. Sci. 64:422–427.

Cicek H, Thiessen Martens J, Bamford K, Entz M. 2014. Effects of grazing two green manure crop types in organic farming systems: N supply and productivity of following grain crops. Agric. Ecosyst. Environ. 190:27.

Cicek H, Thiessen Martens JR, Bamford KC, Entz MH. 2014. Effects of grazing two green manure crop types in organic farming systems: N supply and productivity of following grain crops. Agric. Ecosyst. Environ. 190:27–36.

Connor DJ. 2008. Organic agriculture cannot feed the world. F. Crop. Res. 106:187–190.

Connor DJ, Mínguez MI. 2012. Evolution not revolution of farming systems will best feed and green the world. Glob. Food Sec. 1:106–113.

Cox CM, Garrett K a., Bockus WW. 2005. Meeting the challenge of disease management in perennial grain cropping systems. Renew. Agric. Food Syst. 20:15–24.

Cox T, Van Tassel D, Cox C, DeHaan L. 2010. Progress in Breeding Perennial Grains. Crop Pasture Sci. 61:513.

Cox TS, Bender M, Picone C, Van Tassel DL, Holland JB, Brummer EC, Zoeller BE, Paterson a. H, Jackson W. 2002. Breeding Perennial Grain Crops. CRC. Crit. Rev. Plant Sci. 21:59–91.

Cox TS, Glover J, Van Tassel D, Cox C, DeHaan L. 2006. Prospects for Developing Perennial Grain Crops. Bioscience 56:649–659.

Crews TE. 2005. Perennial crops and endogenous nutrient supplies. Renew. Agric. Food Syst. 20:25–37.

Crews TE, Blesh J, Culman SW, Hayes RC, Jensen ES, Mack MC, Peoples MB, Schipanski ME. 2016. Going where no grains have gone before: From early to mid-succession. Agric. Ecosyst. Environ. 223:223–238.

Crews TE, Dehaan LR. 2015. The Strong Perennial Vision : A Response. Agroecol. Sustain. Food Syst. 39:500–515.

Crowle W. 1966. The Influence of Nitrogen Fertilizer, Row Spacing, and Irrigation on Seed Yield of Nine Grasses in Central Saskatchewan. Can. J. Plant Sci. 46:425–431.

Cui S, Allen V, Brown P, Wester D. 2013. Growth and Nutritive Value of Three Old World Bluestems and Three Legumes in the Semiarid Texas High Plains. Crop Sci. 53:329–340.

Culman SW, DuPont ST, Glover JD, Buckley DH, Fick GW, Ferris H, Crews TE. 2010. Long-term impacts of high-input annual cropping and unfertilized perennial grass production on soil properties and belowground food webs in Kansas, USA. Agric. Ecosyst. Environ. 137:13–24.

Cunningham SA, Attwood SJ, Bawa KS, Benton TG, Broadhurst LM, Didham RK, McIntyre S, Perfecto I, Samways MJ, Tscharntke T, et al. 2013. To close the yield-gap while saving biodiversity will require multiple locally relevant strategies. Agric. Ecosyst. Environ. 173:20–27.

Darwent AL, Najda HG, Drabble JC, Elliott CR. 1987. Effect of Row Spacing on Seed and Hay Production of Eleven Grass Species Under a Peace River Region Management System. Can. J. Plant Sci. 67:755.

Davis AS, Hill JD, Chase CA, Johanns AM, Liebman M. 2012. Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. PLoS One 7:1–8.

Dawson IK, Vinceti B, Weber JC, Neufeldt H, Russell J, Lengkeek AG, Kalinganire A, Kindt R, Lilles?? JPB, Roshetko J, et al. 2011. Climate change and tree genetic resource management: Maintaining and enhancing the productivity and value of smallholder tropical agroforestry landscapes. A review. Agrofor. Syst. 81:67–78.

DeHaan L, Van Tassel D. 2014. Useful insights from evolutionary biology for developing perennial grain crops. Am. J. Bot. 101:1801.

DeHaan L, Van Tassel D, Cox T. 2005. Perennial grain crops: A synthesis of ecology and plant breeding. Renew. Agric. Food Syst. 20:5–14.

DeHaan LR, Van Tassel DL, Cox TS. 2005. Perennial grain crops: A synthesis of ecology and plant breeding. Renew. Agric. Food Syst. 20:5–14.

DeHaan LR, Wang S, Larson SR, Cattani DJ, Zhang X, Kantarski T. 2013. Current Efforts to Develop Perennial Wheat and Domesticate Thinopyrum Intermedium as a Perennial Grain. In: Batello C, Wade L, Cox S, Pogna N, Bozzini A, Choptiany J, editors. Perennial Crops for Food Security: Proceedings of the FAO Expert Workshop. Rome, Italy: Food and Agriculture Organization of the United Nations. p. 72–89.

Dewey D. 1978. Intermediate Wheatgrasses of Iran. Crop Sci. 18:43–48.

Doherty D. 2016. Darren J. Doherty CV. Regrarians. [accessed 2016 Jun 12]. http://www.regrarians.org/about/darren-j-doherty-cv/

Dotzenko A. 1961. Effect of Different Nitrogen Levels on the Yield, Total Nitrogen Content, and Nitrogen Recovery of Six Grasses Grown Under Irrigation. Agron. J. 53:131–133.

Ekers M, Levkoe CZ. 2016. Transformations in agricultural non-waged work: From kinship to intern and volunteer labor. J. Agric. Food Syst. Community Dev. Advance on:179–183.

Entz M, Thiessen Martens J, Martens G, Carkner M, Lynch D, Kopecky M, Podolsky K. 2015. Co-design of organic farming systems on the Canadian Prairies. In: Gritti E, Wery J, editors. Proceedings of the 5th International Symposium for Farming Systems Design. Montpellier, Fr. p. 423–424.

Entz MH, Baron VS, Carr PM, Meyer DW, Smith SRJ, McCaughey WP. 2002. Potential of forages to diversify cropping systems in the northern Great Plains. Agron. J. 94:240–250.

Entz MH, Bullied WJ, Forster DA, Gulden R, Vessey JK. 2001. Extraction of subsoil nitrogen by alfalfa, alfalfa-wheat, and perennial grass systems. Agron. J. 93:495–503.

Entz MH, Guilford R, Gulden R. 2001. Crop yield and soil nutrient status on 14 organic farms in the eastern portion of the northern Great Plains. Can. J. Plant Sci. 81:351–354.

Erenstein O. 2002. Crop residue mulching in tropical and semi-tropical countries: An evaluation of residue availability and other technological implications. Soil Tillage Res. 67:115–133.

Fairey NA. 2006. Cultivar-specific management for seed production of creeping red fescue. Can. J. Plant Sci. 86:1099–1105.

Falk B. 2013. The Resilient Farm and Homestead: An Innovative Permaculture and Whole Systems Design Approach. White River Junction, VT: Chelsea Green Publishing.

Famiglietti JS. 2014. The global groundwater crisis. Nat. Clim. Chang. 4:945–948.

Ferguson BG, Diemont SAW, Alfaro-Arguello R, Martin JF, Nahed-Toral J, Álvarez-Solís D, Pinto-Ruíz R. 2013. Sustainability of holistic and conventional cattle ranching in the seasonally dry tropics of Chiapas, Mexico. Agric. Syst. 120:38–48.

Ferguson RS, Lovell ST. 2014. Permaculture for agroecology: Design, movement, practice, and worldview. A review. Agron. Sustain. Dev. 34:251–274.

Ferguson RS, Lovell ST. 2015. Grassroots engagement with transition to sustainability: Diversity and modes of participation in the international permaculture movement. Ecol. Soc. 20.

Food AA and. 1992. Shelterbelts in Alberta. Agri-Facts Pract. Inf. Alberta's Agric. Ind.:1–4. [accessed 2016 Jun 13]. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2995

Frick B. 2013. Weeds: Organic Principles. In: Frick B, editor. Organic Farming on the Prairies. 2nd ed. Regina, SK: Saskatchewan Organic Directorate. p. 55–76.

Friedrich T, Derpsch R, Kassam A. 2012. Overview of the global spread of conservation agriculture. F. Actions Sci. Reports:1–7.

Le Gal PY, Dugue P, Faure G, Novak S. 2011. How does research address the design of innovative agricultural production systems at the farm level? A review. Agric. Syst. 104:714–728.

Gentile RM, Martino DL, Entz MH. 2005. Influence of perennial forages on subsoil organic carbon in a long-term rotation study in Uruguay. Agric. Ecosyst. Environ. 105:419–423.

Giampietro M. 2004. Multi-Scale Integrated Analysis of Agroecosystems. Boca Raton, FL: CRC Press.

Gilker R. 2013. Keyline Plowing: What is it? Does it work? Pasture Transl. Res. Exp. into Pract. you can use NOW! [accessed 2016 Jun 14]. http://onpasture.com/2013/06/17/keyline-plowing-what-is-it-does-it-work/

Giller KE, Witter E, Corbeels M, Tittonell P. 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. F. Crop. Res. 114:23–34.

Gliessman S. 2007. Agroecology: the ecology of sustainable food systems. New York, NY: CRC Press, Taylor & Francis.

Gliessman S. 2012. Agroecology: Growing the Roots of Resistance. Agroecol. Sustain. Food Syst. 37:19–31.

Glover J, Culman S, Dupond ST, Broussard W, Young L, Mangan M, Mai J, Crews T, DeHaan L, Buckley D, et al. 2010. Harvested perennial grasslands provide ecological benchmarks for agricultural sustainability. Agric. Ecosyst. Environ. 137:3.

Glover J, Reganold J, Bell L, Borevitz J, Brummer E, Buckler E, Cox C, Cox T, Crews T, Culman S, et al. 2010. Increased Food and Ecosystem Security via Perennial Grains. Science (80-.). 328:1638–1639.

Goplen B. 1981. Norgold - A Low Coumarin Yellow Blossom Sweetclover. Can. J. Plant Sci. 61:1019–1021.

Green JO, Evans TA. 1957. Grazing Management for Seed Production in Leafy Strains of Grasses. J. Br. Grassl. Soc. 12:4–10.

Grime J. 2002. Plant Strategies, Vegetation Processes, and Ecosystem Properties. 2nd ed. Chichester, UK: John Wiley & Sons, LTD.

Grime P. 2001. Plant Strategies, Vegetation Processes, and Ecosystem Properties. New York, NY: Wiley.

Groot JCJ, Jellema A, Rossing WAH. 2010. Designing a hedgerow network in a multifunctional agricultural landscape: Balancing trade-offs among ecological quality, landscape character and implementation costs. Eur. J. Agron. 32:112–119.

Halde C, Bamford KC, Entz MH. 2015. Crop agronomic performance under a six-year continuous organic no-till system and other tilled and conventionally-managed systems in the northern Great Plains of Canada. Agric. Ecosyst. Environ. 213:121–130.

Hayes RC, Newell MT, DeHaan LR, Murphy KM, Crane S, Norton MR, Wade LJ, Newberry M, Fahim M, Jones SS, et al. 2012. Perennial cereal crops: An initial evaluation of wheat derivatives. F. Crop. Res. 133:68–89.

Hedley C. 2015. The role of precision agriculture for improved nutrient management on farms. J. Sci. Food Agric. 95:12–19.

Heide OM. 1994. Control of flowering and reproduction in temperate grasses. New Phytol. 128:347–362.

Hemenway T. 2009. Gaia's Garden: A Guide to Home-Scale Permaculture. 2nd ed. White River Junction, VT: Chelsea Green Publishing.

Holechek J, Pieper R, Herbel C. 2011. Range Management: Principles and Practices. 6th ed. Upper Saddle River, NJ: Prentice Hall.

Holmgren D. 2002. Permaculture: Principles & Pathways Beyond Sustainability. Hepburn, Au: Holmgren Design Services.

Holzer S. 2004. Sepp Holzer's Permaculture. Graz, Austria: Leopold Stocker.

Hopkins A, Krenzer E, Horn G, Goad C, Redmon L, Redfearn D, Reuter R. 2004. Spring Grazing Reduces Seed Yield of Cool-Season Perennial Grasses Grown in the Southern Great Plains. Agron. J. 95:855.

Hoveland C, Townsend C. 1985. Other Legumes. In: Heath M, Barnes R, Metcalfe D, editors. Forages: The Science of Grassland Agriculture. 4th ed. Amex, IA: Iowa State University Press. p. 146–153.

Hybner R, Jacobs J. 2012. INTERMEDIATE WHEATGRASS (Thinopyrum intermedium L.): An Introduced Conservation Grass for Use in Montana and Wyoming. NRCS−Montana−Technical Note−Plant Mater.:1–8.

Jacke D, Toensmeier E. 2005. Edible Forest Gardens: Ecological Vision and Theory for Temperate Climate Permaculture. White River Junction, VT: Chelsea Green Publishing.

Jackson W. 1980. New Roots for Agriculture. Lincoln NE: University of Nebraska Press.

Jackson W. 2002. Natural systems agriculture: A truly radical alternative. Agric. Ecosyst. Environ. 88:111–117.

Jacobo EJ, Rodríguez AM, Bartoloni N, Deregibus VA, Jacobo EJ, Rodrı AM, Bartoloni N, Deregibus VA. 2006. Rotational Grazing Effects on Rangeland Vegetation at a Farm Scale

Rotational Grazing Effects on Rangeland Vegetation at a Farm Scale. Rangel. Ecol. Manag. 59:249–257.

Jaikumar NS, Snapp SS, Murphy K, Jones SS. 2012. Agronomic assessment of perennial wheat and perennial rye as cereal crops. Agron. J. 104:1716–1726.

Jansen K. 2000. Labour, Livelihoods and the Quality of Life in Organic Agriculture in Europe. Biol. Agric. Hortic. 17:247–278.

Jonsdottir GA. 1991. Tiller Demography in Seashore Populations of Agrostis-Stolonifera, Festuca-Rubra and Poa-Irrigata. J. Veg. Sci. 2:89–94.

Kanga JS, Kanengoni AT, Makgothi OG, Baloyi JJ. 2012. Estimating pasture intake and nutrient digestibility of growing pigs fed a concentrate-forage diet by n-alkane and acid-insoluble ash markers. Trop. Anim. Health Prod. 44:1797–1802.

Kassam A, Friedrich T, Shaxson F, Pretty J. 2009. The spread of Conservation Agriculture: justification, sustainability and uptake¹. Int. J. Agric. Sustain. 7:292–320.

Knowles RP. 1977. Recurrent Mass Selection for Improved Seed Yields in Intermediate Wheatgrass. Crop Sci. 17:51–54.

Kobrich C, Rehman T, Khan M. 2003. Typification of farming systems for constructing representative farm models : two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agric. Syst. 76:141–157.

Kropff MJ, Bouma J, Jones JW. 2001. Systems approaches for the design of sustainable agro-ecosystems. Agric. Syst. 70:369–393.

Lawrence T. 1957. Emergence of Intermediate Wheatgrass Lines from Five Depths of Seeding. Can. J. Plant Sci. 37:215–219.

Lawrence T, Ashford R. 1966. The Productivity of Intermediate Wheatgrass as Affected by Initial Harvest Dates and Recovery Periods. Can. J. Plant Sci. 46:9.

Lawrence T, Ratzlaff CD, Jefferson PG. 1991. Emergence of several Triticeae range grasses influenced by depth-of seed placement. J. Range Manag. 44:186–187.

Lawrence T, Warder FG, Ashford R. 1971. Effect of Stage and Heigh of Cutting on the Crude Protein Content and Crude Protein Yield of Intermediate Wheatgrass, Bromegrass, and Reed Canarygrass. Can. J. Plant Sci. 51:41.

Lee DK, Owens VN, Boe A, Koo BC. 2009. Biomass and seed yields of big bluestem, switchgrass, and intermediate wheatgrass in response to manure and harvest timing at two topographic positions. GCB Bioenergy 1:171–179.

Ljungblad S, Holmquist L-E. 2007. Transfer scenarios: grounding innovation with marginal practices. In: Proceedings of the SIGCHI conference on Human factors in computing systems. San Jose, CA: ACM. p. 737–746.

Lockeretz W. 2012. What Explains the Rise of Organic Farming? In: Lockeretz W, editor.

Organic Farming: An International History. Oxfordshire, UK: CABI. p. 1–8.

Lovell ST, DeSantis S, Nathan CA, Olson MB, Ernesto Mendez V, Kominami HC, Erickson DL, Morris KS, Morris WB. 2010. Integrating agroecology and landscape multifunctionality in Vermont: An evolving framework to evaluate the design of agroecosystems. Agric. Syst. 103:327–341.

Madry W, Mena Y, Roszkowska-Madra B, Gozdowski D, Hryniewski R, Castel JM. 2013. An overview of farming system typology methodologies and its use in the study of pasture-based farming system : a review. Spanish J. Agric. Res. 11:316–326.

Malézieux E. 2012. Designing cropping systems from nature. Agron. Sustain. Dev. 32:15–29.

Martens JT, Entz M, Wonneck M. 2013. Ecological Farming Systems on the Canadian Prairies Ecological Farming Systems on the Canadian Prairies.

Martin G, Martin-Clouaire R, Duru M. 2013. Farming system design to feed the changing world. A review. Agron. Sustain. Dev. 33:131–149.

Martin K, Sauerborn J. 2013. Agroecology. Dordrecht, Netherlands: Springer Netherlands.

McCartney D. 2016. Extended Grazing. BCRC Beef Cattle Res. Counc. [accessed 2016 Jun 16]. http://www.beefresearch.ca/research-topic.cfm/extended-grazing-45

McKenzie R, Heinrichs D, Anderson L. 1946. Maximum Depth of Seeding Eight Cultivated Grasses. Sci. Agric. 26:426–431.

Meeh DC, Rowntree JE, Hamm MW. 2013. Feeding a population with smaller scale and alternate system production: An examination of farm requirements with a multi-species pasture system to feed 10 million people. Renew. Agric. Food Syst. 29:1–10.

Meyer RS, DuVal AE, Jensen HR. 2012. Patterns and processes in crop domestication: an historical review and quantitative analysis of 203 global food crops. New Phytol. 196:29–48.

Michaud R, Richard C. 1992. AC Caribou Alfalfa. Can. J. Plant Sci. 72:845–847.

Montgomery DR. 2007. Soil erosion and agricultural sustainability. Proc. Natl. Acad. Sci. U. S. A. 104:13268–13272.

Murphy DJ, Hall CAS. 2010. Year in review-EROI or energy return on (energy) invested. Ann. N. Y. Acad. Sci. 1185:102–118.

Murray H. 1993. Whole Farm Case Studies: An Interdisciplinary Approach to Systems Research. Oregon State University.

Murray H. 1994. Whole farm case studies: An Interdisciplinary Approach to Systems Research. Oregon State University.

Nelson KA, Smoot RL, Meinhardt CG. 2011. Soybean response to drainage and subirrigation on a claypan soil in northeast Missouri. Agron. J. 103:1216–1222.

Odum H. 1971. Energy, Power, and Society. Hoboken, NJ: John Wiley & Sons, LTD.

Paige KN, Whitham TG. 1987. Overcompensation in Response to Mammalian Herbivory : The Advantage of Being Eaten. Am. Soc. Nat. 129:407–416.

Palm C, Blanco-Canqui H, DeClerck F, Gatere L, Grace P. 2014. Conservation agriculture and ecosystem services: An overview. Agric. Ecosyst. Environ. 187:87–105.

Panettieri M, Lazaro L, López-Garrido R, Murillo JM, Madejón E. 2013. Glyphosate effect on soil biochemical properties under conservation tillage. Soil Tillage Res. 133:16–24.

Papaïx J, Burdon JJ, Zhan J, Thrall PH. 2015. Crop pathogen emergence and evolution in agro-ecological landscapes. Evol. Appl. 8:385–402.

Pashaei F, Linden A Van Der, Meuwissen MPM, Cunha G, Oude AGJM, Boer IJM De. 2016. Environmental and economic performance of beef farming systems with different feeding strategies in southern Brazil. Agric. Syst. 146:70–79.

Paul BK, Vanlauwe B, Ayuke F, Gassner A, Hoogmoed M, Hurisso TT, Koala S, Lelei D, Ndabamenye T, Six J, et al. 2013. Medium-term impact of tillage and residue management on soil aggregate stability, soil carbon and crop productivity. Agric. Ecosyst. Environ. 164:14–22.

Pham L Van, Smith C. 2014. Drivers of agricultural sustainability in developing countries: A review. Environ. Syst. Decis. 34:326–341.

Phelan P. 2009. Ecology-Based Agriculture and the Next Green Revolution. In: Bohlen P, House G, editors. Sustainable Agroecosystem Management: Integrating Ecology, Economics, and Society. New York, NY: CRC Press, Taylor & Francis. p. 97–135.

Picasso V, Bummer EC, Liebman M, Dixon PM, Wilsey B. 2008. Crop Species Diversity Affects Productivity and Weed Suppression in Perennial Polycultures under Two Management Strategies. Crop Sci. 48:331–342.

Pimentel D, Cerasale D, Stanley RC, Perlman R, Newman EM, Brent LC, Mullan A, Chang DTI. 2012. Annual vs. perennial grain production. Agric. Ecosyst. Environ. 161:1–9.

Pollan M. 2006. The Omnivore's Dilemma. London: Penguin Press.

Ponisio LC, M 'gonigle LK, Mace KC, Palomino J, De Valpine P, Kremen C. 2015. Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B Biol. Sci. 282:1–7.

Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI. 2014. Food Security and Food Production Systems. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, et al., editors. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY: Cambridge University Press. p. 485–533.

Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE. 2010. Global pollinator declines: Trends, impacts and drivers. Trends Ecol. Evol. 25:345–353.

Pridham JC, Entz MH. 2008. Intercropping spring wheat with cereal grains, legumes, and oilseeds fails to improve productivity under organic management. Agron. J. 100:1436–1442.

Prieto I, Violle C, Barre P, Durand J, Ghesquiere M, Litrico I. 2015. Complementary effects of species and genetic diversity on productivity and stability of sown grasslands. Nat. Plants 1:1–5.

Redmon L, Krenzer E, Bernardo D, Horn G. 1996. Effect of wheat morphological stage at grazing termination on economic return. Agron. J. 88:94.

Reganold JP. 2012. The fruits of organic farming. Nature 485:176.

Reganold JP, Wachter JM. 2016. Organic agriculture in the twenty-first century. Nat. Plants 2:1–8.

Righi E, Dogliotti S, Stefanini FM, Pacini GC. 2011. Capturing farm diversity at regional level to up-scale farm level impact assessment of sustainable development options. Agric. Ecosyst. Environ. 142:63–74.

Rochon JJ, Doyle CJ, Greef JM, Hopkins A, Molle G, Sitzia M, Scholefield D, Smith CJ. 2004. Grazing legumes in Europe: A review of their status, management, benefits, research needs and future prospects. Grass Forage Sci. 59:197–214.

Rodríguez-Estévez V, García A, Peña F, Gómez AG. 2009. Foraging of Iberian fattening pigs grazing natural pasture in the dehesa. Livest. Sci. 120:135–143.

Ross MA, Harper JT. 1972. Occupation of Biological Space During Seedling Establishment. J. Ecol. 60:77–88.

Ruhlemann L, Schmidtke K. 2015. Evaluation of monocropped and intercropped grain legumes for cover cropping in no-tillage and reduced tillage organic agriculture. Eur. J. Agron. 65:83–94.

Ryszkowski L. 2002. The Functional Approach to Agricultural Landscape Analysis. In: Ryszkowski L, editor. Landscape Ecology in Agroecosystems Management. Boca Raton, FL: CRC Press. p. 1–7.

Sakschewski B, Von Bloh W, Huber V, Müller C, Bondeau A. 2014. Feeding 10 billion people under climate change: How large is the production gap of current agricultural systems? Ecol. Modell. 288:103–111.

Salatin J. 2010. The Sheer Ecstasy of Being a Lunatic Farmer. 1st ed. White River Junction, VT: Chelsea Green Publishing.

Santillano-Cazares J, Redfearn DD, Caddel J, Goad C, Hopkins A. 2008. Winter Grazing can be Beneficial to Tall Fescue Seed Production in Oklahoma. Forage Grazinglands Res. 6.

SAS. 2012.

Savory A, Butterfield J. 1999. Holistic Management: A New Framework for Decisionmaking.

2nd ed. Washington, DC: Island Press.

Schindler D, Hecky R, McCullough G. 2012. The rapid eutrophication of Lake Winnipeg: Greening under global change. J. Great Lakes Res. 38:6–13.

Schroeder W. 2012. Eco-Buffers : A High Density Agroforestry Design Using Native Species Introduction. In: Haase D, Pinto J, Riley L, editors. National Proceedings: Forest and Conservation Nursery Associations-2011. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. p. 72–75.

Schulte R. 2001. On the stability of mixed grasslands. Wageningen University.

Scialabba NE-H, Müller-Lindenlauf M. 2010. Organic agriculture and climate change. Renew. Agric. Food Syst. 25:158–169.

Sempore AW, Andrieu N, Le Gal P-YY, Nacro HB, Sedogo MP. 2016. Supporting better crop-livestock integration on small-scale West African farms: a simulation-based approach. Agroecol. Sustain. food Syst. 40:3–23.

Shepard M. 2013. Restoration Agriculture: Real World Permaculture for Farmers. Austin, TX: Acres USA.

Shreck A, Getz C, Feenstra G. 2006. Social sustainability, farm labor, and organic agriculture: Findings from an exploratory analysis. Agric. Human Values 23:439–449.

Siegfried T, Bernauer T, Guiennet R, Sellars S, Robertson AW, Mankin J, Bauer-Gottwein P, Yakovlev A. 2012. Will climate change exacerbate water stress in Central Asia? Clim. Change 112:881–899.

Silvertown J, Poulton P, Johnston E, Edwards G, Heard M, Biss PM. 2006. The Park Grass Experiment 1856-2006: Its contribution to ecology. J. Ecol. 94:801–814.

Site WR. 2015. Research. Woody Perenn. Polycult. Res. Site Large-Scale Res. a Savanna-Based Agroecosystem. [accessed 2016 Jun 13]. http://wppresearch.org/research/

Smaje C. 2015. The Strong Perennial Vision: A Critical Review. Agroecol. Sustain. Food Syst. 39:471.

Smil V. 2002. Nitrogen and Food Production: Proteins for Human Diets. AMBIO A J. Hum. Environ. 31:126–131.

Smith JR. 1929. Tree Crops: A Permanent Agriculture. New York, NY: Harcourt, Brace, and Company.

Smith RE, Veldhuis H, Mills GF, Eilers RG, Fraser WR, Lelyk GW. 1998. Terrestrial Ecozones, Ecoregions and Ecodistricts: An Ecological Stratification of Manitoba’s Natural Landscapes. Brandon, Mb: Land Resource Unit, Brandon Research Centre, Research Branch, Agriculture and Agri-Food Canada, Winnipeg, Manitoba.

Smith T, Smith R, Waters I. 2014. Elements of Ecology: Canadian Edition. Toronto: Pearson.

Smith-spangler C, Brandeau ML, Hunter GE, Bavinger JC, Pearson M, Eschbach PJ, Sundaram V, Liu H, Schirmer P, Stave C, et al. 2012. Are Organic Foods Safer or Healthier Than Conventional Alternatives ? Ann. Intern. Med. 157:348–366.

Średnicka-Tober D, Barański M, Seal C, Sanderson R, Benbrook C, Steinshamn H, Gromadzka-Ostrowska J, Rembiałkowska E, Skwarło-Sońta K, Eyre M, et al. 2016. Composition differences between organic and conventional meat: a systematic literature review and meta-analysis. Br. J. Nutr. 115:994–1011.

Sun H, Tang Y, Xie J. 2008. Contour hedgerow intercropping in the mountains of China: A review. Agrofor. Syst. 73:65–76.

Sylvestre D, Lopez-Ridaura S, Barbier JM, Wery J. 2013. Prospective and participatory integrated assessment of agricultural systems from farm to regional scales: Comparison of three modeling approaches. J. Environ. Manage. 129:493–502.

Tang X, Shi D, Xu J, Li Y, Li W, Ren Z, Fu T. 2014. Molecular cytogenetic characteristics of a translocation line between common wheat and Thinopyrum intermedium with resistance to powdery mildew. Euphytica 197:201–210.

Tarnoczi TJ, Berkes F. 2009. Sources of information for farmers' adaptation practices in Canada's Prairie agro-ecosystem. Clim. Change 98:299–305.

Van Tassel D, De Haan L. 2013. Wild plants to the rescue. Am. Sci. 101:218–225.

Van Tassel DL, Dehaan LR, Cox TS. 2010. Missing domesticated plant forms: Can artificial selection fill the gap? Evol. Appl. 3:434–452.

Tavernier EM, Tolomeo V. 2004. Farm Typology and Sustainable Agriculture : Does Size Matter ? Farm Typology and Sustainable Agriculture : Does Size Matter ? J. Sustain. Agric. 24:33–46.

Teague R, Provenza F, Kreuter U, Steffens T, Barnes M. 2013. Multi-paddock grazing on rangelands: Why the perceptual dichotomy between research results and rancher experience? J. Environ. Manage. 128:699–717.

Teague WR, Dowhower SL, Baker SA, Haile N, DeLaune PB, Conover DM. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. Agric. Ecosyst. Environ. 141:310–322.

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418:671–7.

USDA-GRIN. Trifolium repens L. "Canadian Ladino." U.S. Natl. Plant Germplasm Syst. [accessed 2016 Jul 5]. https://npgsweb.ars-grin.gov/gringlobal/accessiondetail.aspx?1221271

Verhulst N, Govaerts B, Verachtert E, Castellanos-Navarrete A, Mezzalama M, Wall P, Chocobar A, Deckers J, Sayre KD. 2010. Conservation agriculture, improving soil quality for sustainable production systems? In: Lal R, Stewart B, editors. Advances in Soil Science: Food Security and Soil Quality. Boca Raton, FL: CRC Press. p. 137–208.

Vico G, Manzoni S, Nkurunziza L, Murphy K, Weih M. 2016. Trade-offs between seed output and life span - a quantitative comparison of traits between annual and perennial congeneric species. New Phytol. 209:104–114.

De Vries W, Kros J, Kroeze C, Seitzinger SP. 2013. Assessing planetary and regional nitrogen boundaries related to food security and adverse environmental impacts. Curr. Opin. Environ. Sustain. 5:392–402.

Wagoner P. 1989. Intermediate wheatgrass grain production trials at the Rodale Research Center: 1988 summary. Rodale Press.

Wagoner P. 1990. Perennial Grain Development - Past Efforts and Potential for the Future. CRC. Crit. Rev. Plant Sci. 9:381–408.

Walker LR, Wardle DA. 2014. Plant succession as an integrator of contrasting ecological time scales. Trends Ecol. Evol. 29:504–510.

Watt D. 1989. Economic Feasibility of A Perennial Grain: Intermediate Wheatgrass. In: Wagoner P, Gardner J, Schatz B, Sobolik F, Watt D, editors. Grass or Grain? Intermediate Wheatgrass in a Perennial Cropping System for the Northern Great Plains. Vol. 108. Kutztown, PA: North Dakota State University, Fargo/Rodale Research Center. p. 11–13.

Welch RY, Behnke GD, Davis AS, Masiunas J, Villamil MB. 2016. Using cover crops in headlands of organic grain farms: Effects on soil properties, weeds and crop yields. Agric. Ecosyst. Environ. 216:322–332.

Wezel A, Bellon S, Doré T, Francis C, Vallod D, David C. 2009. Agroecology as a science, a movement and a practice. Sustain. Agric. 2:27–43.

Wiens MJ, Entz MH, Martin RC, Hammermeister AM. 2006. Agronomic benefits of alfalfa mulch applied to organically managed spring wheat. Can. J. Plant Sci. 86:121–131.

Wojtkowski P. 2004. Landscape Agroecology. Binghamton, NY: Food Products Press.

Wolfe MS, Baresel JP, Desclaux D, Goldringer I, Hoad S, Kovacs G, Löschenberger F, Miedaner T, Østergård H, Lammerts Van Bueren ET. 2008. Developments in breeding cereals for organic agriculture. Euphytica 163:323–346.

Wolfenbarger L, Phifer P. 2000. The Ecological Risks and Benefits of Genetically Engineered Plants. Science (80-.). 290:2088–2093.

Yeomans P, Yeomans K. 1993. Water for Every Farm: Yeomans Keyline Plan. Netley, South Australia: Griffin Press.

Zhang JH, Wang Y, Zhang ZH. 2014. Effect of terrace forms on water and tillage erosion on a hilly landscape in the Yangtze River Basin, China. Geomorphology 216:114–124.

7.0 APPENDICES

7.1 Appendix A: List of Abbreviations

IWG	Intermediate wheatgrass
SOM	Soil organic matter
CA	Conservation agriculture
OA	Organic agriculture

7.2 Appendix A: Initial Consent Form

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Winnipeg, MB
Canada R3T 2N2
Telephone (204) 474-8221
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Informed Consent Form

Research Project Title: Documenting and Classifying Existing Ecological Farming Techniques in Western Canada

Principal Investigator and contact information: Calvin Dick (email: umdick8@myumanitoba.ca)

Research Supervisor: Martin Entz (tel: 204-474-6077, email: M.Entz@umanitoba.ca)

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the Research:

The purpose of the research is to gain knowledge about integrative and innovative farming practices and management on the Canadian Prairies. There are many new ideas with great promise for increasing sustainability and environmental benefits while maintaining production, but because of their novelty, complexity and (often) long-term nature it is challenging to study them in academia. Some of the questions I am hoping to answer (or begin to answer) are:

What ideas are farmers implementing?
How well do they seem to be working (economically; environmentally)?
How do farmers understand what they are doing? What do they want to know?

With that information, I hope to

- Start to organize these ideas and techniques (which are largely isolated from each other in academia) into a coherent conceptual framework
- Pave the way for valuable future experiments
- Make the case studies available to all farmers so that they can adopt or adapt these ideas (if appropriate) with less risk as well as being able to share their own ideas

Ultimately, assuming that the ideas fulfill their theoretical and anecdotal promise, I hope that this research will result in greater security, independence, and profitability in the agricultural sector and improved food security and sustainability for society as a whole.

Your Role in the Research:

As a participant farmer, your role will be to participate in an interview, give me a guided tour of the farm (I hope to take pictures), provide me with or help me create a map of the farm, and provide me with some work to do on the farm. This will be a one-time event although there may be some follow-up questions or correspondence. The duration of the interview will likely be between 2 to 4 hours, the tour will depend on the farm, and I expect to work for about an 8 hour day. The total involvement time should be about 2 days.

Please note that the 8 hour work day will be in lieu of direct financial compensation for your time.

I will take notes on the interview by hand as well as recording them with a Roland R-05 Wave/MP3 Recorder. The interview questions will be sent to you in advance in order to help you prepare and to allow you to give me feedback if you have any.

Please sign here if you are willing to allow the interview be audio recorded:

____

Potential Benefits

The potential benefits of participating are:
1. Getting feedback and new ideas about possible ways to improve or optimize your farm
2. Having the opportunity to connect with and learn from other farmers who are trying similar things in different parts of the Prairies.

The longer term benefits are:
1. Increased research support from academia.
2. Better market access as consumers and producers become more familiar with these practices and crops.

Potential Risks

The risks I have identified are:

1. You may find the questions upsetting.
2. There may be a negative reaction from neighbors or the local community.
3. There may be greater competition in the future in a niche market you are taking advantage of.

Again, you are not required to answer any question you are uncomfortable with.

Confidentiality

The potential benefits for both you and for the research will be greatest if the data collected is neither confidential nor anonymous. However if you wish to keep your information confidential, only the collected data that cannot be used to identify the participant will be used in the study (as part of the conceptual framework). Audio and computer files for these participants will be encrypted, and written notes will be stored in a locked office.

Your individual case study will be sent to you for your approval before being made public.

Any confidential data will be destroyed no more than one month after the thesis is submitted.

Withdrawing from the Study

Participants may withdraw from the study at any time before, after or during the interview. This can be done verbally in person, over the phone, or via email.

Debriefing

There will not be a debriefing for this study but participants are welcome to review the interview questions and summary of the project in advance, ask questions and make suggestions.

Dissemination

The results of the study will be used to fulfill part of the requirements for my Master's thesis. They will be shared with my committee and the broader academic community via written reports, posters and presentations. If the results are useful, I hope to make them available to the public over the internet or email.

Summary of Results

Your case study will be sent to you before October 2015, either as a paper copy or an email. If you wish to receive the case studies that are to be made public or the integrated analysis (or both) in the final report please indicate that here: ___________________________

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Joint-Faculty Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

Participant's Signature _________________________ Date ____________

Researcher and/or Delegate's Signature ___________________ Date _______

7.3 Appendix C: Second Informed Consent Form for Anonymized Case Studies

University of Manitoba | Faculty of Agricultural and Food Sciences

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Informed Consent Form

Research Project Title: Documenting and Classifying Existing Ecological Farming Techniques in Western Canada

Principal Investigator and contact information: Calvin Dick (email: umdick8@myumanitoba.ca)

Research Supervisor: Martin Entz (tel: 204-474-6077, email: M.Entz@umanitoba.ca)

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

What is this Consent Form?

This consent form is in addition to the original that you signed before or at the interview in 2015. The purpose of this consent form is to get formal permission from you to include the case studies as an appendix within my Master's thesis. Although this has been the intent all along, it was not clearly expressed in the original.

Furthermore, after writing up your case study based on the interview, some participants and my advising committee have suggested that for the purposes of the study the participants should be able to choose their level of anonymity given that the case studies included in the thesis will be publically available worldwide. This consent form will allow you to choose whether you wish to remain identifiable, fully participate in the study while protecting your identity, or to remain anonymous.

Purpose of including the Case Studies in the Thesis

The purposes of the case studies is to serve as reference for the analysis and to act as an informational resource for the study, other researchers, farmers, and the public. They should allow the reader to have an intermediate understanding of the farm systems within their environmental, social, and economic context which in most circumstances is more useful and interesting than a narrow academic discussion. They should also enable the reader to draw inspiration for certain approaches or further research in ways not discussed by the thesis.

Your Role in the Research

At this point, you have reviewed and at least indicated that your case study is acceptably accurate in representing your farm and attitudes. Your role now is to review your case study, having a better understanding of how it will be used in the project and decide how you would like to have it presented (or not).

Potential Benefits and Risks

The potential benefits of choosing to not remain anonymous or mostly anonymous include

1. Greater potential to make connections with other farmers, to share ideas and compare strategies.
2. Greater potential to form relationships with academic institutions interested in performing further research.
3. Potentially increased market exposure.

However, this is offset by risks that include

1. Potential harassment from individuals or groups.
2. Unwanted public exposure and loss of privacy.
3. Possible negative reactions from local community members.

While both benefits and risks will still exist by choosing to remain mostly anonymous, their extent will be much reduced. It is maybe worth noting that the likelihood that the case studies will be read as part of the thesis is quite small.

Withdrawing from the Study

As has always been the case, you may choose withdraw from the study at any time. This can be done verbally in person, over the phone, or via email. The last date you will be able to choose to withdraw your participation will be June 30, 2016.

Dissemination

Hopefully, the case studies (anonymized or not) will be included as part of an Appendix of the thesis. I also hope to share them among all of the participants in the form that they have chosen.

In light of the information above, I believe there are now three options assuming you wish to continue to participate. Please check the box next to the option that you prefer.

☐ Given this new information, I do not wish for my case study to be included in the appendix of the thesis even though my unidentifiable information will still be included in the analysis and discussion of the thesis.

☐ I wish to have my information anonymized, i.e removing names, locations, and other features from the case study as appropriate. The edited case study will be approved by me before inclusion in the appendix of the thesis.

☐ I wish that my name and identity remain associated with the information of the case study. The case study will be approved by me before inclusion in the appendix of the thesis. The information in the analysis and discussion of my thesis will remain unidentifiable.

If you feel that there are other options that you would prefer, please let me know.

Thank you again for participating in the study! I have personally learned a great deal and am eager to share the case studies with you once everyone is comfortable with the information being released.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Joint-Faculty Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

Participant's Signature _________________________ Date _____________

Researcher and/or Delegate's Signature ____________________ Date _______

7.4 Appendix D: Farm Case Study Interview Questions

What is your name?
How long have you been farming?
How did you become a farmer?
Did you start out farming the way you do today or has your approach changed over time (if so, what caused the change)?

Describe the topics below as they pertain to the farm:
- climate
- soil type
- water supply and quality
- drainage
- slope/aspect
- wildlife
- environmental issues (e.g. contamination, noise, oil and gas, wind towers)
- history of use
- typical surrounding farm systems
- distance to markets
- access to markets (i.e. transportation infrastructure – roads, rail, internet)
- access to food processors
- your knowledge of the farm environment pre-European contact

(to be accompanied with map or satellite photo of the farm as an aid)
How large is the farm?
How much of it is being actively farmed?
Where are the different fields/zones on the farm?
Are there any natural or artificial landscape features (e.g. hills, gullies, dams)?
What are the uncropped areas on the farm (e.g. waterways, wetlands, hedgerows)?
What are the topographies of the different fields?
Are there any variations in the soils in the farm/are there areas with particular characteristics (e.g. salinity, acidity, unusually high nutrients)?
Have there been any major changes to how any of the fields have been managed over time?

How many extraneous inputs do you buy for the farm?:
- inorganic fertilizer
- manure and compost
- pesticide
- fuel
- machinery maintenance supplies

How much of the farm is in annual cropping vs. perennial?
Which types and how many livestock are being kept on the farm?
How has the management of particular fields changed over time, if at all?

What crops do you sell directly to the market?
What crops do you not sell (e.g. green manures, forages, unmarketable yet still useful crops)?
Do you get any direct benefits from uncropped areas (e.g. firewood, herbs, greens, berries, mushrooms, etc.)?
What livestock species and varieties do you raise on the farm, either for market or for personal use?
What particular non-crop plant, insect or animal species do you have that are still valuable?
What purposes do they serve?
What non-crop plant, insect, animal or disease species do you have that are problematic?
What are your strategies for managing them?
Are there any other enterprises on the farm (e.g. recreational tourism, education, syrups, flowers, beeswax and honey)?

Are there any specific methods or techniques that you use on your farm (e.g. conservation agriculture, rotation, intercropping, polyculture, Keyline, controlled disturbance, holistic grazing management, crop-livestock integration, successional planning in perennial systems, predator and pest control strategies)?
If yes, how have they been applied and what adaptations have you made? Alternatively, do you combine or make use of several principles from different techniques?
What inputs do you need in order to make them work (e.g. infrastructure, seed, plants, markets)?
Are there any neat features of your crops/livestock/environment that you are able to take advantage of (e.g. using herbivory to interrupt a disease life-cycle)?
How do you store your outputs?

----------------------------------(Break for farm tour)---

What ecosystem features and interactions are you trying to capitalize on through your management practices (e.g. water management, soil ecosystem building, succession, predator-prey relationships, canopy layers)?
How do the practices address (or are supposed to address) those features?
From a different perspective, what are the ecosystem services or non-yield functions of the different farm components (e.g. functions like soil retention, nitrogen fixation, species habitat, pest control)?
Does your system contain any functional redundancies (i.e. different components serving the same function in case one fails)?
Where have you gotten your knowledge from (e.g. books, internet, university, observation)?

How do you go about marketing and selling your different products?/What economic connections and strategies do you use (e.g. marketing boards, community supported agriculture, direct marketing, production clubs)?
What kind of social connections and support do you have (or not have) from individuals, families,

communities, institutions?
Who do you rely on in order to make your farm successful?

What are your yields?:
- Marketed crops
- Crops for home use
- Crops with value but no market

What are your yields per unit area?
How have your yields changed over time?
What are your risk management strategies (e.g. crop insurance)?
How does the system handle stress or disturbance (e.g. droughts, floods)?
On an observational level, how does the system perform environmentally (e.g. soil fertility and quality, biodiversity, beneficial insect abundance)?
If you have more than one farm enterprise, how important are they relative to one another?
Do you have any protectable advantages (i.e. something you have access to that would be very difficult for someone else to make use of)?

What motivates you to farm the way you do?
When did you start to think about farming in that way?
What are the biggest challenges you face (in technical, economic and social spheres)?
What are some things that you would do differently if you were starting again?
What have some of the most important learning experiences been so far?
What ideas have you read and thought about but decided not to pursue? Why?
What would you like to know more about?
What are your biggest concerns about the future?

What buildings do you have on the farm, what are their dimensions, purposes and locations?
What infrastructure do you have for your livestock (e.g. barns, watering systems, fences, pens)?
What equipment do you have on the farm (e.g. tractors, combines)?

How many people work on the farm over the course of the year?
Who works on the farm (e.g. family, seasonal labor)?
Do you participate in any subsidized labor programs?
How many total hours does it take to run the farm per year?

7.5 Appendix E: Farm Case Studies

The case studies from Farms B through I are presented below. Farms A and J did not consent to having their case studies published with the thesis and are therefore not included here.

Farm B

Kirsten Benot
Prairie Heritage Farm
http://www.prairieheritagefarm.ca/
Gimli, MB

Background

After spending lots time reading about alternative food production methods, Kirsten wanted to get out and try some herself: Permaculture has lots of great sounding ideas that don't necessarily work as advertised and need to be tested out. Kirsten started 5-6 years ago, buying the property in 2009 and moving out in early 2010. Married with 3 kids, she left a good but unrewarding job with the federal government to start growing food and animals.

Ever since they moved out, she has been developing a plan which has evolved with expert advice, and also through trial and error.

History

Kirsten doesn't know much about pre-European contact. She does know that the Peguis First Nation moved north of Gimli after signing a treaty with the Lord Selkirk Settlers, and that the Icelandic settlement in the area began 125-150 years ago.

Environment

They live in climate zone 3a, with an average of 550 mm of precipitation (rain + snow) per year. Lately, the rain has been coming in more extreme events: this year there was less than 2 inches through September and October, but it normally came in at 3 or 4 inches per event. They will sometimes have 7-8 inches within a week that drowns everything but there are also 6 weeks with nothing.

Being right next to Lake Winnipeg, there is a significant lake influence which makes it warm up a lot later in the spring (the lake stayed frozen forever last year) but their first frost date isn't as early as elsewhere. Nobody in the area plants a garden before June 1st unless they have a greenhouse or cold frame.

The aquifer/well quality on the farm (and in the area) is very good: Crown Royal probably wouldn't be operating a distillery in Gimli if it weren't. The water table is always high, especially after a rain where it is only one foot beneath the surface and there are also man-made flooding issues relating to spillover from the provincial ditch.

Most of the land in the region is class 4 or 5 with a lot of swamp and organic soils, with small fertile belts. The pockets of very fertile land in the region are occupied by family farms that have larger acreage and grow mostly grain. Crops are the exception rather than the rule though, with most farms small and mixed. Alfalfa grows well and hay production is good business. There are a couple dairy farms that do well, which may change with the adoption of the TPP.

One real environmental concern is the drainage. The region has a lot less chemical use according to government maps, which makes sense given the prevalence of pasture and cattle. Most of the cattle farmers don't have intensive operations so spray drift is minimal. There is some peat mining happening in Hecla but that is a good distance away.

Markets and Marketing Strategy

It is 5 miles to the nearest town, and just one hour to Winnipeg with Selkirk even closer.

Kirsten questions how much demand exists in rural Manitoba for market gardens: everyone in the country basically already has a large garden. Part of the reason they bought the property was because of its proximity to cottage country on the lake - Arnes farmer's market is only 5 miles to the north. They are also right outside of Gimli which also has a farmer's market.

They considered purchasing property in the Pembina Valley near Boissevain but it was just too far away. Both Kirsten and her husband hate driving and never want to be more than five miles from town. Their location now lets them ride a bike from the farm into Gimli on a rail trail.

Since they haven't generated much profit, they haven't had to deal with processors. They've dealt with locals for chicken processing for farm gate sales and personal use, and went through Interlake Packers for their pigs when they had them.

Social

They get lots of support from people in the community and at least 4 farm families that are supportive and helpful. The East Interlake Conservation District is also very supportive, with funding and resources for the constructed wetland - which is key for making the whole design work. Their families are both supportive.

Farm

The farm is 72.89 acres. 25-30 of those are fenced in and being developed while the rest is forested bush. Much of the layout of the farm was determined by Sepp Holzer's consultation that picked a site for a new house and then built ponds around it. The ponds were built to help manage the water, provide the opportunity for aquaculture, and as the source of the spoil to construct the berms.

So far sheep sales are the only thing actually making money. The chicken and pig sales have only offset the cost of raising them.

The soils are mostly alkaline, silty clay soils, with one decent swath of loam. The soils hold water very well but the structure has been impacted by years of flooding and poor drainage. There is a very large imperfectly drained area on the property. Only the loam area has good vertical drainage.

The land was supposed to have been class 2/3, which it may be but to date the drainage issue has vastly trumped the soil quality. The house faces a provincial road with a collector drainage ditch that gets water from culverts passing under the nearby highway, where the water then flows into a spillway cut right into the property. This means that their land collects all of the extra drainage.

To say that drainage is a problem would be an understatement between the heavy clay, relatively flat land, overland flooding, and little drainage infrastructure. The constant flooding and saturation has destroyed the soil structure as well as the soil life. It now has a swampy stink which is known locally as sour soil.

There is a 10 foot drop from the Northwest corner to the Southeast extent of the farm. The farm has some depressions and sloughs, a natural wetland, and a pond that was dug by the previous owner.

Because of their proximity to Lake Winnipeg, the farm is limited to 10 animal units, which makes it more suitable as a demonstration site than a true productive farm.

Berms

In order to deal with the drainage problem and create some actual productivity on the land, they have done extensive earth moving (the history of which is discussed in the Landscaping Experience section below). In general, large berms have been dug and built to protect the property from excess water velocity. The water then is let in through culverts to fill a series of ponds and channels, gradually moving its way along the topography gradient to the southeast where it meets a built wetland before leaving the property.

Figure 1. It's a little difficult to see, but the pond (left) is connected to the channel in the left of the picture by a culvert (in the bottom right quadrant). The constructed but still empty wetland is pictured right.

Figure 2. Examples of a retention pond and channel.

Kirsten has planted a mixture of species directly into the subsoil berms to help keep them stable. The cherries and grapes did very well, strawberries and kiwis grew, the hascap survived, but the rhubarb and currants did very poorly. The failure of the currants was probably a mix of the heat and being high and dry. Kirsten was surprised to find that the cherries have developed real roots already, while the hascaps are limited to the bowl-sized pocket of soil they were planted into.

Figure 3. Berm built of subsoil close to the house with diverse mix (described above).

Kirsten seeded more subsoil berm with clover, and the sweet clover established very well and alfalfa started growing as well. The bees really took to the new habitat. They have also tried using clover as a living mulch between 700 planted asparagus plants to deal with intense weed competition (knowing that it would reduce yields for the first couple of years). The birds have been spreading seeds around the farm ever since.

The north side of the northwest berm (which helps to protect from the prevailing winter winds) was seeded with Swiss stone pine and fall rye. The stone pine is a potential pine nut crop that grows on mountaintops, withstanding frigid temperatures and growing taproots. Lower on the berm, saskatoons, hazelnuts and apple trees have been planted to be closer to the water. Other species there are Nanking cherries which will hopefully distract the birds from more desirable species and Juliet Cherries from the University of Saskatchewan. The trees are planted very close, with 1.5 metres between them based on Mark Shepard's system.

Figure 4. Views of the north side of the berm. This is where the off-farm drainage enters the property. The low vegetation cover (especially right) makes it easy to understand why erosion is currently a concern.

Figure 5. Interior of the northwest berm.

They have built a number of hugel beds out of mixed poplar and willow. The big logs hold lots of moisture but also suck a ton of nitrogen out of the surrounding soil. Kirsten finds that they're only a good idea if you have too much to deal with - mixing soil with wood and manure can be a good way to use otherwise wasted materials. Because of the earthworks, the centre area has become a good place to start developing microclimates.

Figure 6. Hugel beds.

Garden Polyculture

Next to the house, Kirsten has established a polyculture garden experiment with a mix of perennial and annual species. The perennial species include raspberry, black currant, hascap, sour cherry, wild plum, lupine, apple, prairie coneflower, yarrow, rhubarb, false sunflower, kiwi and grapevines, iris, day lilies, calendula, chamomile, zinnia, and buckwheat. The annuals are volunteer sunflower, Swiss chard, lettuce, beans, peas, mesclun mix, kale, nasturtium, and squash plants. Apparently all of the plants did very well and required very little maintenance (a little weeding in the first couple of weeks). She is looking forward to replicating the experiment and using it to provide habitat for beneficial insects.

Figure 7. The polyculture garden late in the season.

Kirsten has found rhubarb to be a fantastic weed controller and great plant all around. It has huge beefy roots that go deep into the soil to collect nutrients and are 3-4 inches in diameter. It's easy to cut their stalks and use the leaves as newspaper-like mulch.

Some of the non-crop species functions include
- fall rye: erosion prevention
- clover: nitrogen fixation (they tend to be the only plants that grow)
- sea buckthorn: nitrogen fixation (did very well on subsoil berm)
- lindens, ornamental crabs, viburnum: bird food and habitat
- rhubarb: living mulch that keeps soil moist, provides a weed barrier (especially quackgrass)

Sheep

Their main livestock animal is sheep, which are Baby Dolls/English South Farms heritage breed. They look like miniatures but the ewes still weight 80-100 lbs and the rams are around 120 lbs. Originally a meat breed, they are very sturdy and hard to catch. The fact that they are disease resistant, hardy, and thrifty makes them easier to manage. They raise heritage breeds generally because varieties only get saved if they're grown and eaten. However, the giant deer fluke has caused many of the sheep to die very suddenly without any warning.

They keep the sheep year round, rotating them through 4 paddocks surrounded by temporary fence. They are rotated depending on the condition of the pasture and how the sheep look. They used to have up to 40 (East Friesian) that had access to larger areas before the earthworks. They have reduced their herd size down to 12 because managing more is hard without a tractor, but still keep them because they are tough to get. Their density is low enough that there aren't problems with overgrazing or parasites. For water they have automatic water bowls.

Pork

Pigs are nice to have around seasonally, kept in a paddock close to the yard. Kirsten used them in areas ripped up by equipment for fertilizer and to help even out the ground. They had a sow that was mixed Berkshire and Tamworth, and a nasty Duroc boar. They overwintered 4 pigs one year that they got late in the season. For shelter, they filled polydomes to the top with straw which are also liked by the sheep when it's windy. They fed them with the spoils picked up on regular trips to the city from an organic product place that would have otherwise had to pay tippage fees.

Poultry

The 120 chickens they've kept have been a big success and an excellent addition to the farm, though overwintering them is a hassle. They are Berg's Grazer chickens, which are a fast growing pasture bird. They eat more grass, but don't finish evenly and have a poorer feed conversion than Cornish Cross. They have done Buff Orpington as well, which required little supplemental feed and were excellent at insect eating - constantly leaping into the air to catch things. Kirsten acquired them as a breeding trio of 2 hens + rooster from a heritage breed farm.

The chickens are surrounded by electronet fencing. Kirsten sets up a corridor for them to move into the pasture and calls them back at night with some handfuls of feed. Sometimes stragglers need some extra encouragement. She has considered a mobile hoop house/chicken tractor setup but they are either too heavy or too much work. She did agree that the birds raised in confinement fatten up faster because they can't run around and chase insects. The feed is free choice.

Kirsten had an excellent experience with Muscovy ducks. They never had more than 12 and used them primarily for pest control. In Tanzania, they are used in cattle barns to catch flies - which they do more effectively than commercial fly traps. They were very low maintenance: feeding themselves and hatching out of their own eggs. Kirsten would toss about a handful of feed every night to keep them coming back to the yard, even without clipped wings. Being able to fly up into trees was an excellent predator defense.

Equipment, Inputs and Labor

They purposefully do not have any farm equipment at all (not even an ATV). For infrastructure they have 5000 feet of permanent fence on the perimeter and 6000 feet of page wire with a hot wire. The permanent fence has its benefits but also limits the way in which you think about the space. Their buildings include a pseudo-barn with six stalls, a pseudo hayshed for shelter, hoop houses/chicken coops, and an insulated 1x4 foot coop used as a brooder. They also have a hose pressure fed automatic watering bowl.

They have purchased some hay and straw for animal bedding. Kirsten is thinking about growing garden annuals like tomatoes or herbs at some point and potentially creating some value added products with them.

For labor, Kirsten relies mostly on herself and mentors. She feels lucky to be able to ask people like Bernie Amell for advice and local people like her neighbor Mark are great friends and resources. She doesn't keep track of her hours, but said that the planning, networking, and publicizing require time and work that happens when people normally sleep. She describes it as every waking hour not involved with something else. She does almost all of the work herself, with some help from the family for planting although she has paid for some services and the conservation district has lent some summer students to help plant. Her husband isn't heavily involved because he works full time, but the kids think that the combination of food, wildlife, fish, and water is fantastic.

She finds it a bit ironic that she left working in an office to do garden-related experiments but has ended up spending a lot of time in front of a computer working on grant proposals and outreach material.

Natural

Weeds and Pests

Their weeds include thistles, quackgrass, Dockweed (somewhat), Red Bartsia (not in major amounts), and Reed Canary grass.

A major pest that they've been dealing with is giant deer fluke which has killed many of their sheep in pasture. This is a problem that's becoming more of an issue in the Interlake, with other farmers in the region also condemning beef livers because of the deer fluke. Kirsten suspects that many more farmers are probably affected as well, but they are reluctant to admit they have a problem. This is in large part because there is no drug currently licensed in Canada but Kirsten still finds it frustrating and challenging. Excluding deer from the land is a priority because they eat the trees and deposit the deer fluke.

Cytospora canker spreads primarily from their aspen trees and affects their apples, cherries, and dogwoods. The cherry fruit fly has been causing their cherries to rot early. Most online advice recommends intensive chemical control (spraying 10+ times). Kirsten thinks that biological control, especially with chickens or pigs, might be a viable alternative. Voles are another tree pest which they avoid with tree wraps as well as having a feral barn cat in the yard.

Direct Benefits

There are wild edibles in their bush area but they haven't harvested them in meaningful amounts: filbert hazelnuts, high bush cranberry, wild raspberries and strawberries. There is also plenty of firewood. Unfortunately the hazelnuts mostly get eaten by wildlife and the ones they have harvested almost all have had grubs.

Biodiversity

Even though the ponds are extremely new, they've already had a positive effect on their wildlife. They have a thriving northern leopard frog population and have started seeing bats for the first time. The frogs are deafening in the summer: sometimes it's too loud to walk and talk outdoors. The water and ponds have caused an exponential increase in their bird populations. Earlier in the year there were 5 dozen robins that came and congregated by the water. There are many species of birds that are visiting including six different types of ducks, grebes, cormorant, and osprey a couple of times.

Being in an agriculturally marginal area right next to a large lake means that they have a lot of wild species:

Mammals		**Birds**	**Amphibians**
Black bears	Voles and mice	Eagles (more now with the water)	Toads
Timber wolves	Snowshoe hare	Owls	Garter snakes
Coyotes	Groundhog	Hawks	Northern red belly
Lynx	Red squirrels	Ducks	Leopard frogs
Cougar	13 stripe ground squirrel	Herons	Wood frogs
Fox	Chipmunks	Bitterns	Tree frogs
Weasel	Bats	Sparrows	
Mink	Skunk	Hummingbirds	
Raccoon		Orioles	

Advantages and Challenges

One of Kirsten's advantages is that she seems to have a gift at writing grant proposals. She has only been turned down once, and it may have been because she applied for the wrong grant.

Water may be their greatest challenge, but it is also a major asset and advantage - not only for production but also for fire protection. Before the earthworks it was possible that a dry spell would leave the property vegetation tinder-dry, exposed to events like a fire blown around by 70 kph winds which happened shortly after they moved out one season.

While livestock play a part in the system, the family isn't able to live out there during the winter which makes it so they can only raise animals seasonally.

The most pressing challenge at this stage is to get everything seeded and planted. There is a great deal of disturbed earth that needs to be controlled. Once that's done there are almost too many opportunities. Kirsten expects that these opportunities will be nested - that is that taking advantage of them will create the possibility of more.

Motivation and Concerns

Kirsten's goal with their property is develop a demonstration site and see what's possible in terms of maximizing income, diversity, and maintaining habitat. There are lots of interested people trying to learn more about raising their own food, but there are a lot of substantial barriers blocking the path. She believes that there has to be a better way and she is striving to be one of the people putting things into practice to see what works or not - especially on a challenging piece of land in a challenging climate. What's going on in the world is unsustainable and unhealthy and what they do might be part of the answer.

Kirsten started thinking in this way at least 15 years ago. At the time she was frustrated by inefficiencies in things and was doing research into earthships and sustainable house building. This led to exploring how to grow food without really intensive farming and heating greenhouses. Learning about combining chicken coops with greenhouses introduced her to Permaculture and concepts like storing heated air under greenhouses, and people growing tropical and Mediterranean gardens in Colorado.

A big part of the whole project is to prove that you can create a viable family farm system. She shudders at the idea of people offering internships who have less experience than what she has, setting people up in inadequate trailers and getting them to work long hours yet still struggling to break even.

Perhaps the central question of the farm is whether it has been worth the investment. The questions you have to ask yourself are what the cost is and why are you doing it. Without development there wouldn't be the possibility of making money period - the local advice was to drain the land, deep till, mow, and get animals. To do that though, they would have needed 6 inches of manure to produce enough fertility to grow anything with a cost of $2,000/ac. Alternatively, it's conceivable that they could have created habitat, fertility, and productivity spending less money than they would on a barn or a new pickup truck.

Landscaping Experience

Kirsten is aware that what they've done on the property is quite radical and many will probably question the reshaping of the land. Her response is that they started with unusable land with too much water that killed their trees and their sheep. Her goal is to see if they can create some fertility where there was none before. If the trees had lived, they would probably not have consulted the experts and turned the property into the massive project it became.

Mark Shepard's consultation picked the highest point on the farm to be the spot where to plant trees even though Kirsten knew the spot to always be wet. Against what should have been her better judgment, they planted trees and watched them get flooded and die later on. Shepard's approach to Keyline design was stymied by the flatness of the topography. After wandering around with a laser level trying to find the rise and fall, he finally admitted that the system wasn't going to work.

By contrast, Sepp Holzer, who has developed his system of earthmoving working on the slopes of the Austrian Alps, didn't address the maps and decided that the best course of action was to dig enormous berms, doing one soil test dig for 5 types of glacial till. Digging berms and ponds has created the potential for both opportunities and failures. Holzer mostly talked about how the trees are sick - evidently not appreciating what vegetation normally looks like at the border between parkland and boreal ecozones. In 2014, Kirsten had failed to get a grant to host Holzer in the spring but received one to implement a huge earthworks project based on his recommendations in mid-October (with a deadline of March 1st that later got extended to September 1st, 2015). After hurriedly implementing the recommendations, Kirsten perceives a number of problems and risks.

In Kirsten's estimation, neither consultant had a firm grasp of general water management for their conditions. Rob Avis from Verge Permaculture in Calgary recommended Bernie Amell, who works on huge hydrology projects out of Calgary like the Calgary perimeter greenway and the Ranchlands wetland in Medicine Hat. Excellent to work with, he understands the climate, the natural flow of water, as well as the nature of glacial till. Bernie looked at the waterflow patterns and natural depressions in the property, and recommended that the ponds be turned into a connected series of spillways. Originally they were going to be shallower but because the ground was so wet they opted to pursue a water retention strategy. An important point was that the system should keep the maximum water level constant to avoid overflow.

Figure 8. One of Bernie's suggestions was a protected overflow channel like this to keep the water level stable.

Kirsten has done her best to incorporate all three of the consultations (which includes Bernie's water plan) in such a way that they still satisfy the conditions of her grants. What they've come up with is now able to capture the water but also give excess a place to go.

The cost of the landscaping varied quite a bit. Sepp Holzer and his prescriptions were very costly (nearly $75,000) partly because of communication problems with the backhoe operator, high consultation fees, poor weather conditions, and the fact that it is expensive to dig deep and move lots of earth. Under other circumstances, Kirsten thinks that they could have done the same work for a quarter or third of the cost. By contrast, the smaller channels between ponds created berm space, growing space, and possible grazing lanes, and took just a couple days and cost much less.

If they were starting over, she would probably have made the berms with a more gradual slope and not as high. In spite of the issues, the ponds have now opened up the door to aquaculture and growing aquatic ornamentals like hardy water lilies. The system now makes irrigation very easy, whether by just scooping water directly or pumping water out of the retention ponds.

Learning

Sources

Kirsten's knowledge has come out of the Permaculture literature and institutional sources: online materials, university resources and research - especially from Natural Systems Agriculture and horticulture programs, extension offices, and agricultural resources from the Alberta and Ontario governments. She finds that many of the ideas that have been less tested are coming from people applying them in very different climates, whether it's the Australian Permaculturists, Ben Falk in Vermont, Martin Crawford in a zone 8 climate, or even Daniel Halsey in Minnesota. Bernie Amell has been an enormous help with his great understanding of hydrology and the climate history.

The local farmers have had the greatest insights into the space, and those that understand the regional problems think what they're doing is quite smart (though lots of people think they're crazy).

Lessons Learned

Balancing patience with the desire to make something happen is tough. Kirsten has a tendency to go big but going slow lets you adapt and improve along the way. This has caused problems for them, but now that the earthworks are there they have many pilot projects in partnership with various groups that have created a lot of interesting opportunities.

Getting to know your land is the biggest piece of advice Kirsten has to offer. It's easy to use internet resources to learn about indicator species and figure things out for yourself. In terms of water management it's very helpful to find someone with experience and background in the area - certainly worth doing before planting thousands trees and watching them die. As a rule, be very careful about large earthworks projects, especially if you're living in unique conditions.

Before buying the property, Kirsten put a lot of faith in her pre-research based on maps and the soil survey. Not taking the time to get to know the land resulted in her planting tons of trees and watching them all die. Just looking at the willows growing on the property makes it obvious that it was much less well drained than the maps implied.

If she could go back, Kirsten might not have planted 2500 trees (including willow and dogwood) into ground without any oxygen. Fortunately most of them were from PFRA. The lesson is not to plant right away and test things out before trying them on a large scale.

Finally, they have tried some Keyline subsoiling but it's not applicable where they are.

Interests

Kirsten would like to know more about how to build the soil, have a better understanding of polyculture, biochar, and ramial woodchips. She doesn't like landscape fabric as a mulch but isn't sure about what the best alternative would be - the rhubarb sometimes works. Her ideas now are flax straw (which the voles don't like as much) and planting willows on the shorelines and chopping their branches down as they grow.

Kirsten would have liked to have taken a PDC course but wasn't able to make it to the course offered through Harvest Moon in 2010. More recently she has talked to different Permaculture organizations and locals about hosting a course in Gimli. Unfortunately the cost of hosting is enormous and most Permaculturists (like Verge Permaculture out of Calgary) have an urban focus on yards that are 2500 ft^2.

Future Plans

There are an awful lot of plans Kirsten has to get the system up and running.

In the very near term, Kirsten means to take a bunch of live stakes from willow cuttings to pin down erosion control fabric (jute) and keep it in place. Dogwood is another option. Kirsten also plans to seed the 'roads' to alfalfa, clover and grass with the possibility of grazing.

It will take time before they start selling tree-based produce- at least a couple of years before the (couple hundred) cherries and (5 dozen) apples start to produce and they can start to sell as the farmer's market. It will probably be some time before they start growing crops as well.

They consulted a fisheries biologist about doing aquaculture in their 5 metre deep ponds. He told them that ice fishing is probably their best bet because they'll be available when nobody else has them and they will taste better than harvesting them at a normal time. They will probably start by raising fathead minnows in the small ponds and trout in the big ones. Keeping the waterways clean and not deteriorating the environment will be a focus there.

Because there is always moisture, mushroom cultivation would probably be an excellent pursuit in the area. Other ideas include mutispecies cell grazing, beekeeping, aquaculture, ornamental aquatics, and pumpkins because of the water availability and the usefulness of squash leaves for mulch.

Kirsten is thinking about offering free farm tours. She has already put together brochures about livestock integration for benefits (e.g. breaking up disease cycles), polyculture, microclimates, and water management. They have hosted workshops at the farms that they haven't made money with. People have asked about courses, Kirsten has been invited to speak at events, and schools have asked about farm tours. This might all be good in two or three years, but Kirsten feels that her knowledge is still mostly based in books although she has some ideas now about what works.

Critical Discussion of Permaculture

What Kirsten finds so inspiring about Mark Shepard is that his systematic approach is something that makes it possible for a conventional farmer to understand and consider seriously, through machine harvestability, and using annuals as a method of transitioning to perennial production. This contrasts significantly with other prominent permaculturists like Martin Crawford and especially Sepp Holzer whose systems often evolve out of random chaos. Holzer also comes from a completely different landscape and climate to western Canada, especially the one right next to Lake Winnipeg.

Shepard also says not to worry about spraying crops - just plant rows of trees every 16 feet which lets you keep spraying. The larger farm scale also makes his system more realistic. Nevertheless, his recommendations about crop species may not be entirely appropriate.

Kirsten is a little bit concerned that there is an element of pyramid scheme in the Permaculture world. There are so many design courses and books that are offered now, that seem to quickly become the main source of income for those touting them. Many of these teachers aren't actually farming anymore and Kirsten wonders whether they seem to be doing well because of their farm or because of their books. She has yet to see someone give a straight answer here. The cost of hosting Mark Shepard and Sepp Holzer was extremely high, and even with grant support and participants in their workshops paying quite a bit, she still ended up paying quite a bit out of pocket. After the fact, Kirsten has gotten more calls from people asking about the experience rather than their message.

Some people are charging quite a bit without a strong background in the area at all: she mentioned that there are consultants that charge $250/hr in BC who have a Bachelor's degree in commerce and only did a 72 hour PDC.

Tough Questions

Kirsten has observed that many of the farmers in the Interlake are impoverished even though they work insanely hard. The cattle farmers often get little or no return (e.g. during the BSE crisis they were getting $6/head) and even when they make a profit they never consider the time or labor they put in as an expense. People might be asset rich, but they are cash flow poor and the debts are enormous and just keep growing. She illustrated the point with one of Mark Shepard's stories about an organic potato farmer who lost $10,000 last year. Shepard pointed out that he could just walk into the field and toss potatoes over his shoulder and lose less money. Kirsten believes that there has to be something better than going into debt and breaking your back to raise cattle.

However, after watching them work with Sepp Holzer another farmer asked the following question:

Even if you could support a family on a 100 acre farm (like Mark Shepard), who will you find to do the farming? If you split up a 10,000 acre farm, who will farm the 100 acre plots? People often say that family farms are disappearing because of farm policy, but it's at least as true that kids want to move to the city for better jobs. They are the ones that remember the backbreaking work that farming entails. How do you convince hundreds of thousands of urbanites to go back to that physical labor?

There are those that do, but Kirsten has seen people come out and buy some land and then have the reality of it set in. She suspects that we will go back to the land when we have to. This is rather depressing because the model can feed everyone with less acreage. However, it's impossible for someone with an average income to buy meat for a family of 5 at Vita Health.

Kirsten takes some issue with meat-based production. While it's fine on marginal land, she worries about where the water and hay come from for 7.5 months out of the year. Many animals need grain supplementation as well, which means we're still baling, fertilizing and spraying. For example, in her experience free-ranging chickens, a 6 pound chicken needed 22 pounds of grain, which is a lot of food being diverted from human consumption. If everyone adopts a multi-species grazing approach, what environmental problems will that create as livestock consume and pollute scarce water resources? The point is that animals are able to convert what we can't eat into food, converting grass grown on class 4 land into milk and beef.

Kirsten is somewhat torn on annual grain. After planting a lot of annual rye on her slopes, she sees their value as forage, a cereal grain, erosion protection and slope stabilization, as well as their allelopathic qualities, and their potential to be put into polyculture (especially with legumes). The problem is just that they are planted in vast areas of monocultures to suppress all other forms of life. Garlic is another example of a useful annual because it will perennialize if not all of it is harvested.

Farm C

Vance and Brenda Barritt
Earthworks Farm
http://earthworksfarm.ca/
Alix, AB

Background

Both Vance and Brenda were born and raised on farms but only came back to farming 4 or 5 years ago.

They have both taken slightly different roads to return to the agricultural lifestyle. Vance's path began after taking a Permaculture Design Course in 2010. Though he didn't feel that he had access to enough land to make a living at the time, but afterwards has come to think that a small amount of land is plenty (or too much). Brenda's return to farming came largely through a Master's degree done about Farming Sustainability and her love for food, its role in health, and noticing the effects of poverty extremes on people.

Coming back to farming, they bought 7 of Vance's dad's best Simmental cows in late 2010 (2 cows and 5 heifers). The Simmental genetics don't fit as well now and high prices tempt them to sell, but they are happy with the Scottish Highland crosses they have now. In the following year they purchased 500 chicks and some geese (who ate grass but were put on hold because they were tough to eat, had inconsistent results, and didn't have a processor). In 2011, they also took a holistic management course with Vance's dad and started to seriously think about producing food as a career and setting goals (as well as planning their wedding).

History

Before European contact, there was a significant aboriginal presence in the area, with Battle Creek to the north being a major battleground and no man's land, while Tail Creek (2 miles south) was a gathering place for up to 2000 people for annual buffalo hunts. On their property they've found spearheads and an atlatl in their sandy areas and had visitors from the Alberta Museum of Paleontology looking for artefacts. Their land was also on the edge of the glacier-free zone 9000 years ago, and the extent of the ice is still visible today.

The farm where they are currently living originally belonged to Vance's great-great uncles, and was bought by his granddad in 1938 after the house burned down.

The land they have in the south was settled in 1904 by Vance's great-great-great granddad who moved from Kansas with his family. In those days, the Barritt family was a fairly major land holder. Like many others, they had a mixed farm with pigs, dairy cows, and grain. His granddad was a bit of an unusual Luddite though, being the last in the community to buy a tractor but the first to buy a car.

Vance's dad worked with his uncles and cousins with enterprises and equipment, farming for cows and grain, growing his own hay and silage, even trying veal for awhile. In 1991, his mom took a holistic management course and in the following years sold her equipment and rented her land out for custom grazing. Vance has found that the management has been good for the land, but she hasn't done any fertility management. They are now trying to fix this situation by starting to feed hay on the land. The hay that they buy tends to be of high quality, with the idea that the cattle will preferentially forage for more roughage on the land in order to balance their diet while still helping manage the growing plants.

Environment

The climate near Alix is temperate but hell in winter. There are only some Chinooks at the northern edge of the area. It's frequently dry, averaging 18 inches of rain (and 20 inches of moisture per year), but is still quite variable - notably with the relatively wet past couple of years.

Neighbors and Environmental Problems

The predominant rotation in the area is wheat and canola, with some including barley and nearby Hutterites having planted peas. Some farmers still have cattle - mostly beef with some dairies around Ponoka - and there is a chicken farm 8 miles away. The trend has been more and more towards pure grain, which is just much easier to manage than a mixed or cattle operation which are often at cross-purposes.

Their main environmental issue is a natural gas compressor station adjacent to the property that smells occasionally and brings in weeds (and spray). They once were growing potatoes on the north side of the house, 80 feet from the fence line that died from spray drift. The closest industrial facility is the Nova Petrochemical Plant by Joffre. More naturally speaking, they find that Buffalo Lake splits thunderstorms and acts as a rain shadow, meaning that they usually miss the severe weather that hits the nearby area.

Community and Support

Both of their families are relatively supportive, with nobody trying to help them fail, and their brothers and sisters are some of their best customers. They often fall back on the experience and opinions of their parents even if the parents don't really know themselves. They can often count on volunteer labor, especially from Vance's mom Connie who knows the system, and Brenda's parents who watch their son, help with castration, and drive the seeder and tractor.

There is less support in the immediate community, but quite a bit in the wider group of ecological farmers. This group is made up of a mix of elders and young guns, most of whom think that there should be more collaboration between them (lack of time is the main barrier). This is tempered somewhat by Vance's instinct to see other farmers as competitors.

Any special food-related interests, like the Weston A. Price or Permaculture circles, are very supportive. The National Farmers Union has been good for social marketing and support, with people being further away at first but now showing up closer to home.

Their customer base and investors help through spreading word of mouth and repeat business. There is the possibility of getting them to help finance significant new projects like a new barn or an abattoir.

Marketing Environment and System

They are roughly 100 miles outside of Calgary, where they send a large portion of their meat. While market gardening is something they have considered, it isn't work the hassle of going into the market even once a week. Comparatively, they can freeze their meat or pick it up at the abattoir and take it into the city in a few trips, especially when you already have buyers. As their farm grows, they may start marketing into Red Deer as well. Overall their market access isn't bad.

The limits to their marketing have more to do with distance and access rather than demand. They have had a potential customer in Yellowknife but because of the small scale of their operation and the difficulty of crossing provincial/territorial borders they weren't able to supply her.

Their closest abattoir is 45 miles away in Ponoka. There are other options in the area but the abattoir in Ponoka is a well run business and does a good job of presentation and packaging. They would like to set up their own at some point in order to maintain quality control: they worry about their own meat being affected by other growers' issues. After doing a study in conjunction with Augustana University, they think that this could be feasible.

For their chickens, there used to be a processor within five miles but in their 3rd year of farming he wouldn't do it anymore. Now the closest facility is in Pigeon Lake which is 1.25 hours away. Their turkey processing is also somewhat tenuous. They have so far been processed at a Hutterite colony but the Hutterites don't like to do it (because of the low volume) and they are concerned about biosecurity issues like bird flu which has already wiped out a number of small processors so they are looking at other options. Their geese are processed at Hairy Hill which is roughly two hours away.

The ordering is internet-based with a transparent website that lets the customer know what, how, and how much. Much of their marketing is through networks - they started through the Permaculture community and are also involved with the Weston A. Price community (e.g. attending potlucks). They have also purchased some ads on Facebook.

They have a meat account program for larger volume wholesale orders which gets people to plan their budget, putting $100 down and depositing money after that in order to get their meat in September. This allows Vance and Brenda to market and get their name out there by attending seasonal fairs without necessarily having to have a product on hand.

Direct marketing gives them a bit of a profit buffer, keeping their feed costs relatively low (even with buying some expensive hay) compared to the prices for their animals. 100% of their sales are directly to the consumer – it is mostly wholesale but they’re starting to produce more meat boxes and sausage. Last year, they had extra product which they sold at a farmer's market in Stettler but this year they are already sold out.

Because of their marketing arrangement, they don't see the point in being certified organic. They prefer selling whenever possible to local people that they know personally.

Farm

The site where their house is located is owned by Vance's mom, which they are in the process of buying (although this is a relatively new development that has changed their plans a bit). This quarter has 65 acres of productive land with the rest in conservation easement. They also have 70 acres from the next quarter over.

Figure 1. Some of the conservation easement is visible from the house.

Vance and his sister have an interesting land arrangement: their grandfather split 4 quarters between them in his will but gave their father permanent residency meaning that they have to rent the land from him. For Vance and Brenda, this means that they have access to 3.5 of his dad's quarters. On the most southernmost, the Nature Conservancy of Canada was interested in creating another easement but they have since backed away from it.

The soil is mostly a sandy loam, sometimes being just sand. Generally the bottoms of hills will have 8 to 10 inches of good topsoil but the hills themselves are made out of sand without any topsoil. This texture means that drainage does not pose any problems. The topography of the sand hills is rolling (potentially more than the surrounding area generally), with places that are a bit nerve-wracking to drive a tractor because of the grade.

For water, there is a creek flowing out of Buffalo Lake, but the quality could be better: it is quite alkaline in addition to collecting the runoff from other farms in the area. The high sodium carbonate ($NaCO_3$) can build up somewhat near to sloughs. There is a well and solar power in the area, but they haven't acquired water lines yet.

Crops

They have 25 acres (less than 10% of the land) in annual crops. The rotation involves a green field for two years, then a grain crop of triticale for chicken feed and seed production, followed by pure alfalfa stand for pasture and to replace nitrogen.

Their cover crop management is currently dictated by weed cycles: they need to mow and plot before the weeds go to seed and refill the seed bank. The green field/cover crop is 3 acres this year and is a small seeded oat and awnless (easier on cattle mouths for swath grazing) barley mix although at the time of the interview it was mostly lambs quarters. If this crop ends up working the way they hope, it will be used on 10-20 ac in order to rejuvenate their pasture stands. Currently they are looking to produce seed for future years.

The triticale is being grown on 11 acres and is complemented by the use of swathed barley. An interesting detail of this system is that after the crop is swathed, they will go in with a seed drill to put the cover crop between the swaths. They expect a yield of around 2 tons/ac which comes with about $35/ac of nitrogen fertilizer put in with the seed (vs. the neighbor spending around $100/ac).

Figure 2. Some crop-livestock integration.

The majority of their pastures are made up of brome, Kentucky bluegrass, orchard grass (which is not a good hay species), quack grass and triticale. For the pasture that is west of the creek, plants that were added to the mix included alsike clover, cicer milkvetch, sainfoin, ryegrass, and bromegrass. The high diversity was planted with the idea that the better adapted plants would flourish in different areas. Once they know this, they should be able to carve up the areas into fields that are seeded with species that are best suited to each area.

System

Pigs

They have 3 Berkshire sows with some large black Berkshire cross genetics, 1 Duroc boar, and 25 pigs with mixed genetics.

The pigs take just under 4 months to gestate, are farrowed at the end of November, and take 8 months to finish with the goal of having them done at the end of September (eventually to be fattened on apples and hazelnuts). As the piglets are weaned they have access to forage and bush. They started out with a shelter which they pitched straw for sow nests, but now they allow the sows to move the straw themselves. They have three small shelters with bales available to them.

Figure 3. Pig pen area pictured left. Note the shelters by the gate opening (water is just out of frame to the left). Hungry and curious pigs are pictured right.

They don't give the boar the same feed as the others (because he doesn't need to gain weight) and the sows are fed first with the highest quality feed. The feed that they provide is soy free and GMO free, and contains a lot of barley malt sprouts. Their customers are a strong motivator here, looking to avoid the estrogenic compounds in soy and the health concerns and patent issues associated with GMOs. The pigs will also eat other scraps, roots, fruits, and vegetables. Like the poultry, they don't have a sense of how large a role forage plays in the pigs' diet and (for both pigs and chickens) are playing with the feed set-up.

They would like to be able to fence the pigs in a particular bush patch (which should help establishing new trees) or let them rip up a pasture, but they don't yet have a water system that will let them do that. So far the pigs need to come back to the yard in order to get water and wallow.

They leave the pigs to farrow themselves, and the piglets really benefit from having their natural mothers around. Vance finds that they have to do quite a bit more mothering work with the chickens and turkeys. They have only had one farrowing related death so far, and they suspect that it may have been in part because Vance went to check on them which increased their stress level. An open question they have is how to decide which gilts are the best to save.

Chickens and Poultry

For poultry they have 405 Cornish Cross, 113 Bronze Orlopp turkeys, 12 laying hens (although they have trouble collecting any eggs), and 25 Muscovy ducks. They finish their turkeys in the fall (for Thanksgiving) and chickens in August and September.

Figure 4. Muscovy ducks and laying hens. Their management is fairly informal.

In their first year, their pasture-raised chickens were brooded indoors and pastured inside. The problem was that they didn't do foraging or scratching in the grass. In order to solve it, they built a brooder over the grass to start them right away and move it regularly to keep it clean. In the third year they really noticed that the birds were scratching and had a completely different personality.

The original brooder was more open which let the chicks get everywhere, which has let them to a more closed system to help manage them and to protect them from predators (the magpies started to take advantage of the free meals).

Figure 5. Full view of the chicken brooder (left) and interior of the enclosed space (right). The chicks are free to move into the open air area at any time.

The bids need a certain amount of space, and as they get bigger their range expands beyond the brooder with electric netting to give them a pasture. The shelter is still moved every day (from east to west), keeping them clean and on fresh grass. They've noticed that the bugs leave 20 to 30 minutes after the chickens are let loose. The turkeys are more effective for insect control, hunting for grasshoppers in packs even though their genetics are poor. In the end, the pasture becomes up to an acre where the birds will sometimes escape but almost always will come back in.

The poultry diet varies as they get older, with more protein when they're young. 80-90% of their diet comes from their feed with maybe 10% meat (e.g. tainted pork or beef lung from an abattoir) and bugs. They don't know how much of the birds' calories come from their foraging for bugs, their best guess being based on research reported on ATTRA.org who do hands-on research with small and ecologically oriented farmers.

Cattle

Their cattle herd should finish 2015 with about 90 or 91 cows including calves. The herd has 25 breeding pairs (plus one Jersey milk cow and calf), a number of heifers which they have been keeping to build their herd, and between 20 and 30 steers which are usually pre-sold.

Figure 6. Galloways and the Jersey (left). The herd being moved to a new pasture (right). Note the contoured trenches in the foreground.

If money were no object, Vance would bale graze as much as he could, feeding other people's cattle on 120 acres of their poor land with 5000 bales, then spreading the straw and manure around with harrows. He would be quite comfortable leaving hairy cows exposed on the hill during the winter. They are firm believers in minimizing the work they do for their cattle, especially when it comes to calving which they don't do at all (like the pigs). Because of their genetics, they've only had one loss due to pregnancy.

Their beef is finished on hard native grasses after the frost, laying around in the fall and putting on weight while they chew their cuds as opposed to increased food intake and exercise in spring with slower gains.

In order to tenderize their beef, they let it cool in the abattoir for 3 weeks compared to 3 days in an industrial facility. While this keeps several parts of the animal from getting tough, it limits the scale of their operation because of the demand for storage space.

Water Management

They have 20 acres that has been transformed into a Keyline landscape by creating trenches on topographical contour and planting 1800 hazelnuts in the bottom of the trenches. In between the rows they are growing hay and between the hazelnuts are planning on putting in a pollinator/butterfly promoting mix of mostly native or naturalized flower species. They did some winter grazing in this area for three weeks and found that the cows didn't do that much damage, although they were supplementing their diet with hay on the hilltops (which was also being used to increase the fertility on the sandy hills). Further, they have attached a neighbor's dam to a trench that allows them to catch any of the overflow and direct it onto the hill. The goal is to stop all runoff water from flowing into the creek, allowing it to infiltrate and slowly move through the soil in order to keep the creek flowing longer.

Figure 7. Another view of the swales on contour. The hazelnuts aren't visible (they are hard to see even without a camera).

More specifically, they have dug small ditches with a plow, and then planted hazelnut bushes into the bottom of the trench. The plow used was a single bottom plow bought at auction for $25. They went with the smaller size because the infiltration rate on the sandy hills is high enough (a 1 inch rainfall in 15 minutes produced barely any runoff) that they don't have to worry about drowning. Also, being in those lower spots will give them extra access to water and that weed competition in the trenches will be significantly less than either above or below them. However the pocket gophers fill them up fast, meaning that the ditches do not last as long as would be ideal and planting directly into them makes it difficult to fix. In the future, they will probably dig another line above the existing trenches to help remedy the problem - and looking back would probably have planted the trees below the trench if they had to do it again. Though the infiltration rate is inherently high, there may still be excess runoff in the spring with the melting snow and frozen ground so the ideal trench size might be larger.

They are considering digging another trench, diverting water from the creek by pumping it up and directing it through a clay trench into the sandy hazelnut populated areas.

On the west side of the north quarter, they will probably install a small Keyline to spread some water in the spring although they would plant the trees in a straight line in order to allow for farming and haying. While 60-70% of this field isn't valuable, there is one pocket with clay topsoil and available moisture that would be a good candidate for a market garden.

North of the house being built on the south property, they have put another trench (not on contour) along the driveway with a variety of species, including lilacs, roses, chokecherry, sea buckthorn, hawthorn, sour cherries, currants, crab apples, rhubarb, raspberry, and gooseberry covering between 2 and 3 acres total.

Yields and Importance of Enterprises

Vance and Brenda agree that measuring the yields would be a good thing to do in order to see improvement but they haven't so far beyond knowing that they have enough to get through the summer but not the winter.

Financially, their beef accounts for about 70% of their income, the pork for 20%, and the poultry for 10%. They invest a lot of time and energy for less economic return for their poultry, especially the chickens which they do retail cuts for. However, they use chicken as a gateway meat since it's something that people are looking for and easy to try out a single bird before committing to half a cow.

Infrastructure and Equipment

Their assets include the house, the cabin present on the southern property, Quonset, garage, chicken coop, 3 unheated wooden buildings for tool storage, 3 or 4 movable shelters for the pigs and calves, and 3 large hoop houses that can be greenhouses with 2 being used as chicken brooders. A note here (related to Holistic Management) is that they ask themselves whether anything new they build can be movable and whether Brenda would be able to build it. They have 3 hopper bottom bins to store feed and ultimately automate feeding with.

The equipment that they have includes (importantly) a skidsteer with post hole digger, an Oliver 88 tractor that needs some work, 2 trucks, a flatbed trailer (that gets a lot of use), small livestock trailer, feed wagon, small Kubota tractor and lawnmower, the big tractor and mower used for farm work and oil field mowing, and Connie's (Vance's mom) Electric Ranger. They also have a 10 foot seed drill, harrows, single and triple bottom plow, disc, swather, and a sprayer that is meant to be used with a compost tea brewer and bubbler.

They have a small freezer for storage but they are interested in getting a motorized refrigerator truck (reefer) for storage and as an abattoir cooling room. At the moment they take their animals to the abattoir and deliver it immediately afterwards.

Inputs and Labor

They supplement their fertility with a number of inputs, using lavatory grade phosphorus, calcium used to produce compost tea, a fish emulsion cube, Azumite, regular fertilizer, straw and hay from the neighbors, worm castings, and pig and chicken feed.

Azumite is a mineral rich, non-salt compound that they mix with their cattle feed. They use the same mix to feed both pigs, chickens, and turkeys, which involves loads of barley sprouts picked up every 2 months that they get from Rahr Malting 6 miles away.

Other inputs include diesel for the tractor (which will be $300 this year) and trucks for deliveries (about $200 per month), propane for their chicken brooder.

The labor for the farm is consistently Brenda and Vance putting in full hours. Usually there is 1 full time person running the farm, either Colin or Vance with sometimes someone at half time or two people at full. Their business is incorporated with the trucking and mowing work that Vance does. Colin, who is from Ireland, is an owner/operator in the company who in order to keep his working permit must be paid a significant salary and make money for the company. Vance and Brenda brought him on for 2 years, where he does research (especially refining the chicken system), networking, and business planning. Because Vance usually works off farm in winter and spends significant amounts of time away from home, Colin's presence makes it much less stressful for Brenda who would otherwise be alone on the farm.

Advantages and Challenges

They don't see themselves as having much in the way of unfair advantages. The best candidates are the existing infrastructure (especially the Quonset) and the knowledge they have, both from their upbringing and what they've learned intentionally. Perhaps the most unique thing is that the nearby compressor station has given them free building materials.

They find that their main challenge is time: there are never enough people to do everything you want done in a day. They often make decisions based on the balance between urgency and priority. They compared farming to being an IT person in a business who has tons of great ideas of how to reorganize the system but spends all of their time fixing computers. They have found that Colin is a great asset to the farm with a range of practical skills and an excellent fit in terms of personality (it's much better to work with friends!). Because of the time constraint, finding the money to invest in skills, people, and (in the longer term) environmental conditions is another challenge. Balancing the off-farm work with the farm work is another struggle. They think that the farm would be better if they had the ability to spend time on things that don't have an immediate cash flow.

Marketing is an important challenge (especially from Vance's perspective). Without Brenda's marketing it would have been very difficult, as Vance was not interested in taking his animals to the auction market. They are a little bit worried of selling all of their product if their beef production doubles (which it may yet).

Natural

Weeds and Pests

They have an appreciation for the songbirds and blue birds on the property, but have been plagued by an overabundance of crows and magpies (a flock of 20 to 30 live in the area) that drive away the songbirds in summer. These birds have forced them to be more protective of their poultry than they would prefer, having learned that they eat exposed chicks. The young chicks and turkeys are now protected by a hoop house. There is some evidence that they have been stealing eggs from the layers as well. The other animal pest they have is coyotes who have gotten some turkeys in fall, though this is probably a fencing problem. If more coyotes move in, they may need to get another guard dog.

When it comes to beavers and gophers, while they are well acquainted with their pest characteristics, Vance and Brenda also see them as an important part of the prairie with beaver dams slowing water movement in streams and creeks while gopher holes can dramatically increase infiltration during massive rain events. This view lends itself to a management approach to gophers (especially) through either reducing their populations by growing taller grass and putting up raptor poles to increase predation, or mowing the grass to maintain a more favourable habitat.

Their weeds are toad flax, evening primrose and yarrow. The toad flax has benefits, being a dynamic accumulator that brings nutrients to the surface but is too widespread to pick. It should be outcompeted by grass (though not necessarily by the trees) eventually. The others aren't serious problems although they take up a lot of space. In order to manage the weeds, they are using long term strategies including using little disturbance and succession and fertilizer or fish emulsion to help correct the mineral balance.

They find that they have fewer disease problems in their cattle than others, which may have something to do with the genetics. They've noticed that darker hoofed animals tend to do better than those with lighter ones. Their main problem is foot rot, which is most likely caused by drinking directly out of the creek and wading into the mud. Fencing it out should dramatically reduce the issue.

Figure 8. Cows next to the creek. Not having it fenced off means that the cows will often go right in to get a drink. Having the freedom to cross to the other side also makes them harder to move.

They have a Darwinian philosophy when it comes to vaccination, believing that even if they lose some, the survivors will be more resilient. In spite of this, they do administer shots for mastitis and will treat the calves with antibiotics (although this hasn't been an issue yet).

There is also a problem with high chick mortality, which may be disease related but is likely due to the less resilient genetics of the commercial breed they have. They haven't had any issues with their pigs to date.

Biodiversity and Benefits

The wildlife that they have or have seen on the property include white and mule deer, the odd moose, an apparent wolf/husky cross, lots of coyotes, beaver and muskrat, lots of waterfowl (ducks and geese), magpies, crows, song birds, and signs of bears at the creek (which makes them concerned for their beehive). Apparently 8 black bears and 4 cougars have been seen by Buffalo Lake.

Vance hopes for the return of beavers to the creek in order to create a stable reservoir of water. This would allow them to fence out the creek and pump water to the cows, reducing their problem with root rot and helping them move the cows more easily.

They don't get any direct benefits from the uncropped areas, although they hope to use much of their bush as pig habitat at some point soon. Some of the indirect benefits are just the enjoyment of the wild areas and the biodiversity that they bring.

Risk

Functional redundancy and multifunctionality is something that Vance and Brenda think about quite a bit. They believe that everything should have planned redundancy which can allow them to adapt if necessary, even if they never have to or want to take advantage of them (e.g. because they might be too labor intensive). An example is their extensive asparagus and hazelnut planting, which isn't something that they are counting or planning on using as an income stream, but still has that potential while it provides food for people and animals as well as capturing snow and acting as a shelterbelt. Other examples include using their pigs to till the soil in their garden (followed with a set of harrows) and capturing rainwater off of the Quonset used for helping raise their meat birds.

Drought and the cost of hay was the biggest worry at the start of 2015, and whether they would be able to feed everyone or have to get rid of some of the sows and boars. The diversity of their enterprises is their main source of resilience by being somewhat independent from each other and being able to adapt to conditions as they change. For example, during years with poor grain prices they would save more grain vs. selling it in a better year or, if the pork must be destroyed there's still the beef and chicken. In theory the perennials are a long term risk management strategy, especially planting fruit trees on the north side of hills to avoid early maturity getting hit with a late frost.

While they try to promote biodiversity and resilience to disturbance wherever they can, it hasn't really been tested yet. At this point there is a certain amount of faith to what they're doing when it comes to increased productivity or even anecdotal benefits, but they don't see themselves as worse off because of it. They are very curious to see how the native and seeded pastures respond differently during years of drought.

A frustration of theirs is that other farmers seem to be farming based on their insurance, like the great return on moisture insurance. While Vance and Brenda don't approve of this system, they feel that there's no sense in not taking advantage of it. Therefore, they have spring and summer pasture insurance for moisture (but no animal insurance).

Techniques

They have been doing some experimentation with adapting Keyline philosophy and plowing to their land. They don't see much need for subsoiling (which is recommended by Yeomans and Mark Shepard) because it's relatively easy to substitute something much cheaper and the freeze-thaw cycles prevent the compaction that the tillage regime is meant to deal with. However, they have adapted the Keyline philosophy in putting in ditches on the hillsides and are planning to do some ripping to manage root suckering in the future.

Holistic management is an important part of their conceptual approach when it comes to looking at the big picture and asking hard questions. It helps them have a good understanding of what they're doing by getting them to go answer a series of questions and to meet and discuss any major decisions to see if they make sense. In terms of the rotational grazing aspect, the cattle are less managed than they would prefer (especially in spring) but their busy spring schedule makes it impracticable.

A good example of their holistic thinking was their desire to have a mower in order to clip their pastures – either to cut the toad flax fields before the grass goes to seed or to help maintain grass health when their cattle can't keep up with the growth. They decided that they weren't willing to take on the debt of buying a mower and tractor, but instead were able to make a deal with someone who was looking for mowers on contract. In the end, it ended up being more work than they were expecting for 2 months out of the year but it's been balanced by the added income stream and the benefit of having a mower and tractor on the farm.

Permaculture is another influence, looking at their property in terms of zones (e.g. keeping their greens close to the house), observing and interacting with their placement of the trees, hazels, and asparagus, and finally holding onto water as long as possible which ties in with their Keyline design. In order to slow the movement of water and energy further (in order to use it before it flows off of the property), they want to plant shelterbelts and encourage the beavers to slow the stream. They are also interested in trying out some hugelkultur (creating raised garden beds by piling soil on top of wooden branches).

They believe that holistic management and Permaculture should be taught together because they're extremely complementary.

Motivation and Concerns

They are motivated to farm the way they do because it's the food that they want to eat. They believe in having and producing nourishing food for themselves, their family and communities, using functional ecology as the production medium. Ultimately they want to nourish life in all forms from the soil to people. Their young son is also a motivator, giving them a daily reminder of who the next generation is and grounding their motivation to improve the world.

The turning point came for Brenda in January 2010 with an email from Don Ruzicka, who, as a friend showed her the potential of ecological resilience and rural community. The email opened up the path, consolidating her experience, passion, and the people she was connected to. For Vance, who planned to create an ecohome subdivision when he moved back to Canada, the shift was more of a slow evolution, starting with the holistic management course 30 years ago (which was about managing grass and reducing equipment). However, he didn't really start thinking this way until after his Permaculture course and meeting Brenda.

They see themselves as part of a group of younger people that are coming back to the farm from an urban background. Brenda has seen a number of people and farmers having minor and major crises in their lives but keeping themselves from releasing from their life or farm models that aren't working very well. She is strongly influenced by Gunderson and Holling's 2002 work that describes how systems move through cycles of reorganization, exploitation, conservation and release. She sees this both at a personal level and a societal level, where our unsustainable society appears to be due for release and reorganization itself. Preparing for this change is something that they value, striving to develop relationships, knowledge and skills to create a safety net that will allow them to be a part of the reorganization. On a personal level, there is a tension for her with the adult education and job training work that Brenda does because she sees it as making people useful for a broken system.

Vance and Brenda are trying to get people to converge in their thinking by planning tours around the idea of showing people what they have and then getting the people to think of what they would do.

Their concerns for the future are mostly fairly big picture. They are worried that either things won't change fast enough to stave off upheavals in the future or that it's already too late to make meaningful change happen. They are less concerned about the planet itself which will continue without humanity, but are more concerned about seeing and living through what we may do to each other as the environment becomes less hospitable to us. They see our society as being like awkward adolescents gaining their own independence, and while we need to go through that phase there's a chance that we might not make it there.

On a much more immediate and practical level, Vance worries about being called out on having too much toad flax and having to spray and crop those fields. This would create some serious issues with their customers.

Knowledge

Sources

Both Vance and Brenda absorbed a lot of what they know by growing up on the farm, with Brenda being less of a willing learner than Vance. They took slightly different paths to return to agriculture as well, with Brenda seeing it in a new light through her Master's work and Vance's Permaculture experience changing his perspective from there not being enough land to not being enough people.

They've read lots of influential books, but the events that stand out are the Acres USA and Permaculture Voices conferences, the latter of which made them realize that they know enough to move forward with their plans especially with Mark Shepard saying that he would have expanded his operation faster if he did it again.

They have been mentored by Don Ruzicka and others connected to him, and are starting to learn a lot more from others through Facebook and 'action inquiry research from farmers right in the field'. They strive to meet one farmer per month. The Holistic Management Course has also been profoundly helpful in their farming approach. Another nearby farm has been especially influential, starting farming with a feedlot but changed their farming model because of health concerns, similarly to Don Ruzicka. Vance's mom and her holistic management practice has had an important effect on Vance as well.

Organizations that they've learned from and are associated with are the Grey Wooded Forage Association, the Farmer's Union, and Acres USA. They've also found help from the government: Alberta Ag has a department that focuses on agricultural support and direct marketing. The department has brought in experts like Toso Bozic and Mark Wonneck, and held marketing workshops in the past.

Another influential thinker is Margaret Wheatley who looks at systems from a social or Buddhist perspective and how people choose different ways of being. Brenda sees this as overlapping with Gunderson and Holling, and as an approach that minimizes the bad while keeping the good – like a hospice worker helping someone to die peacefully. Nevertheless, there is a tension between this approach when it comes to society versus being an activist working to start reorganizing and rebuilding society sooner rather than later.

Lessons Learned

Looking back, they feel that networking and building your own learning are definitely good things to invest in. Although they have been on the farm for five years now, it still feels to them like they’re still just starting out. They are not entirely sure whether it would have made sense to dive right in to a larger scale for many of the things they’ve done – some things have worked out well but they also bought an incubator that hasn’t ended up being used at all.

After getting a bunch of teenagers out to help plant their trees, they think that sometimes it’s better to have less people doing it right than more people getting the job done – more hands does not always mean having more time. Another thing that they’ve learned is when it’s okay to ask for help and being okay with things not being done the way you would have done them. As a couple, they find that it’s worth taking time to connect every day in order to agree on what is a priority.

Future Enterprises and Learning

They have a number of ideas that they haven't been able to pursue so far, mostly because of time and energy. These include geese (not enough information), bees (they have them as a hobby but not as an enterprise), hatching their own birds to get good genetics for raising on pasture, producing eggs for off-farm sale (not enough time), and an enterprise revolved around Keyline design and tree planting. This last one would require developing a full business plan. They are keen to build an abattoir for their beef and pork.

Enterprises that they are working towards include the fruit and nut trees, many of which have been already planted, setting up a compost operation, and making associations with other people that are willing to either help/develop the existing enterprises or develop their own, complementary enterprise on the property. The idea would be to build a brand and then retire one day, collecting money on the land rents.

Some other ideas that they have include having people come out to butcher their own chicken, getting a couple dairy cows for themselves, renting out chickens to city people (e.g. to schools as a learning opportunity), vermicomposting, a tree nursery, or market gardening. They are also looking to improve their fence quality on the southern pastures by starting to use portable fencing. They are considering taking 18 acres, piping water to the centre and improving the pasture by rotating the cattle in a pinwheel fashion.

They would like to know more about the feed ratios you need to produce great geese on pasture. For their pork and beef they want to have trustworthy information when it comes to balancing taste with product quality with animal health. Again, knowing how much feed their chickens get on the grass and the pigs get from the bush would be very valuable. Having a better understanding of the local water cycle and how it can be affected by human action would also be valuable. Finally, butchery, root cellaring, and food preservation are all skills that they would like to have a better handle on.

Philosophy and Direction

They are quite aware of their presence at the border between prairie and parkland biomes. When they are planting trees, they are thinking about the natural poplar to spruce succession and how they can mimic that with similar yet productive species like Korean Pine and Tamarack. With their animals, they are trying to capture the role of large ruminants on the Prairie with their cows and using the pigs (eventually) to help clean out the stagnant understory of their bush areas which don't have the benefit of fire disturbance. They hope to get more spruce trees growing in these areas by putting seed down after the pigs go through, although spruce seed is relatively expensive and hard to get.

Ultimately, they would like to have a leader-follower system (similar to Joel Salatin) where the different animals would work in concert to maximize the efficiency, productivity and overall health of the system. Similarly, their perennial plantings and intercropping haven't been overly planned out but are quite diverse in order to see what works. Their approach to getting there is to have the different elements present on the farm and gradually have them converge as they have time to think about how they might fit together. This slower approach which they describe as an idea of belonging contrasts with 'togethering' which, while much faster, forces elements to work together creating unforeseen glitches or dynamics. Going more carefully allows deeper belongings to happen and elements to find their way together. This lets you make choices that are more thoughtfully considered and less tied to a particular idea, and also lets you be surprised by interesting discoveries.

The list of ecological components that they are trying to enhance are building better soil fertility (with the animals, for the animals), using their tree plantings to support their pastures – especially considering that they have witnessed the opposite of trees creating more drought-like conditions, using the trees and expanded water structures to create microclimates and potentially eventually affect local rainfall patterns, and generally enhancing the aesthetics of their land which could serve for U-Pick wildcrafting or cross country skiing in winter. They find that having the conservation areas on the property are good reference points, allowing them to observe the connections and processes taking place there and compare that to the restorative agriculture they're practicing.

Criticism of Conventional Farming

One of the big frustrations that they have with modern farming is that people are growing commodities for profit rather than growing food for people. Their criticism of precision farming is that it turns the farmer into an unthinking operator that can be replaced by a machine. You can't respond to the environment when you're driving an air-conditioned tractor and not walking the land to notice, see, and understand it. They contrast this with the farmer as specialist, who has gotten to know the land and what to do with it. Similarly, they find a tension between having greater production with greater diversity (e.g. having 2 or 3 different biomes on one landscape) and the convenience of using equipment.

Farm D

Takota Coen
Grassroots Family Farm and Deep Roots Design
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Ferintosh, Alberta

Background

Takota has lived on the farm his entire life and was literally born there. He has been 'legally' farming for 2 years, although it has essentially been a full time unpaid job for that time and he's been working two jobs to support his farming habit.

Growing up, it was an unspoken thing that you couldn't make a living as a farmer. While you could grow your own food there wasn't any money in it, so he got a journeyman ticket out of high school while his sisters went to University. About halfway through the process though, he started doing research on our food system and realized that nobody knew how to grow food so at 19 he figured out he wanted to farm.

3 or 4 years ago, Takota discovered Permaculture and immediately clicked with its ethics and common sense factor. He had been watching documentaries about how bad the food system is, and found it while googling alternative farming techniques – leading him to take his first Permaculture Design Course in June 2012. More recently, he has started to teach others as of about a year ago.

History

Before European contact, the farm was used as a buffalo jump, evidenced by arrowheads and skulls by the cliff dropping into the lake. There are also some burial grounds in the area which has motivated some archeological investigation.

The land started to be farmed from the 1930s onwards as a grain farm (even on the steep slope). The soils were originally excellent but over time the soil collected in the valleys, where in some areas nearly 6 feet of soil has built up.

The farm was originally bought in 1984 by Takota's parents and farmed conventionally (with Grandpa) until 1986 where they switched to organic/no chemical management. While they aren't currently certified, they have been on and off during that time.

When Takota's parents started to manage the farm organically, they had a seven year hay followed by two years of grain rotation up until the first swale was put in two years ago. They would break up 1/5 of the land to refresh them every year. With the benefit of hindsight, Takota pointed out that it wasn't very smart to plow anything above 18° (or 5° for that matter).

After 27 years, they realized that just not using chemicals did not equal good farming. Twenty years ago, the land used to yield 100 fifty pound bales per acre for the first cut and 50 for the second cut. Today, they are only able to take one cut which yields 40 bales/ac (with 50 being a really good yield). They are still producing hay for sale, but now they aren't baling all of the straw and are selective about what they remove - tilling some of the residue in.

Environment

The farm is located in the parkland biome: a mix of aspen and spruce forest with grassland areas. Historically the grass was maintained by herds of roaming buffalo and elk.

The climate of the farm (like most of the prairies) is a dry continental climate – or cold desert where evaporation exceeds annual rainfall. The continental climate means there is a huge temperature swing from -40°C in the winter to +40 in the summer without any moderating effect of a large water body. The climate is erratic as well: they have had snow and frost in every month except July and had temperatures above zero in every month of the year. The rain shadow from the mountains leaves them with 12 inches of precipitation annually (with 3 inches in 2002 being the lowest ever which resulted in a total hay failure). However, 2013 and 2014 both had 24 inches of precipitation. Nevertheless, while there are big thunderstorms every year that pass them by because the nearby lake creates a small rain shadow.

Neighbors

Almost all of the other farms in the region follow a wheat-canola rotation unless they are struggling with fusarium, in which case they start including peas. The good soil means that land prices are extremely expensive (a quarter section recently sold for $5,000/ac) and there is little grazing, which also means that farmers are cutting down trees in order to increase their acreage.

The land next door is farmed by a Hutterite community, who seem to be the only people with enough money to succeed with the conventional farming model. The way their communities are structured and their huge operations that include pigs, chickens, dairies, and grain give them a huge advantage when it comes to profiting off of low margins. However, by mid-June they had already sprayed 4 times for fusarium and weeds, they have bulldozed trees and wetlands - even on land almost too steep to drive a tractor on, and have massive erosion gullies that have moved thousands of tons of soil.

Environmental Issues

The main environmental issues in the area are the chemical spray drift from the neighbors and oil and gas development. In order to address the drift, they are letting trees grow up around the property as a buffer. Takota sees it as being only a matter of time before the oil development results in contamination of the aquifers, and thinks that dugouts and wet wells will be the way of future access to clean water.

Marketing Environment and Strategy

Camrose (population 15,000) is their primary customer base. While there are 50,000 people within a half hour drive and 2 million within an hour, they aren't keen to market into Edmonton and Calgary. Although Camrose isn't the best place for an alternative market, the distance to the larger centers makes it hard to maintain a connection with their customers and Camrose has a number of retired farmers who are starting to rethink how they farmed.

They do their delivery through Food Hubs. These are basically just a drop-off location that makes the logistics easy on both the producer and consumer. Even though they would get a better price by selling at farmer's markets, they find it much better to make their transactions beforehand. They deliver 20-40 dozen eggs to Camrose once a week, and generally meet directly with their consumers to deliver their meat. They ask for a 50% down payment for their meat (which provides some insurance if there's a problem) and get customers to pay $100 for eggs per month.

They don't do any on farm slaughtering, driving one hour to the provincially inspected facility in Forsburg. Alberta used to have 2 mobile abattoirs but one was sold into BC and the other is owned privately in the Peace Country.

Their main marketing strategy is education. They offer free farm tours and Takota does outreach and public speaking that appeal to people’s common sense factor. Takota’s does not see himself as a salesman competing with other farms, and rather tries to get people to support farms like theirs. They usually have customers contact them which lets them get buyers that are genuinely interested and committed to what they’re doing, effecting change in the way that they can.

Everything they produce is direct marketed (with some tables of food at farm days), almost all of which goes to Camrose with some in Calgary and Edmonton. They prefer to sell farther away only when they have to.

Many of the trees were planted as part of a perennial Community Supported Agriculture (CSA), where they raised $9,000 with the same set up as a vegetable CSA where customers bought a $1,000 or $500 share over 4 years. The customers then get a percentage back every year that ends up being 110% of their investment. Last year they got back 10% which included eggs, pork, honey, vegetables and a chicken and this year the return will be 30%. This helped both to let people know what they’re doing on the farm and also helps to further establish their market. The people who bought shares also came out to help plant some of the trees. Takota is considering using the model to help build a barn as well or funding it with low interest personal loans. He would prefer to keep his funding local and away from the banks.

Since the interview he has acquired another $17000.00 in community loans for other farm projects i.e. swales and water system. One loan is 4% simple interest over 5 years and the other ($10,000.00) is 0% interest over 5 years. Many other community members have indicated their willingness and ability to offer affordable loans at present and anytime in the future. Takota estimates that $50,000 to $100,000 could be achieved from community loans for our farm.

Farm (for contour map see Appendix A)

The farm consists of 250 acres of cropland with 20 acres of yard, split between 3 quarter sections (two quarters are cut off by a lake). There are 150 acres (including 10 acres of bush) on the home quarter and 100 on the two partial quarters to the west (which has 30 acres of bush). The bush areas are mostly slough and riparian areas, to which they are adding all the time. They want to maintain 20% of the land as a biological reserve, which shouldn't result in a loss of yield if it is planned properly.

The soil on the farm is a black loam with good organic content over top of clay subsoils, being considered class 1 or 2 land according to Alberta Agriculture's land suitability rating. While the soils have been depleted from the long term hay cropping, they have the potential to turn around relatively fast. Takota has found it necessary to fix the soil first before planting trees – he initially killed three quarters of the apple trees he planted (at $70 apiece). In order to improve the soil in a short time, he has planted green manures for one to two years. Constructing water harvesting swales and waiting for the soil moisture to increase has proved to be even more beneficial.

The farm has a relatively high soil aluminum content, which may be related either to industrial activity or the subsoil parent material. It is of some concern because if the pH drops below 4.5 it becomes mobile and accumulates in plants killing them or making it into the food grown for animals, customers and the family.

The property has land facing every direction, but is dominated by the main ridge that faces SE to SW. There is a 115 foot elevation change from the highest to the lowest part of the farm, ranging from 0 to 25° grade. While it is poor land for machinery, the slope on the hill is the only place to grow certain crops, like heat loving nut trees because for every 1˚ slope increase towards south adds 2 days of growing season.

The worst and hilliest land is located above the topmost swale where they have stopped haying and begun rotational grazing to allow the land to recover. The lower slopes have better soil which they are putting through different rotations until they don't need the hay to sell anymore. They need to sell about 5000 weed-free square bales/year to horse owners in order to maintain their cash flow.

Shelterbelts (associated with the agroforestry/forest garden systems) are integrated everywhere on the property for the purpose of wind protection and water (snow) harvesting. Takota believes that they have the potential to change the amount of precipitation they receive based on the amount of snow they capture. In their dry climate, melting winter snow can provide millions of gallons of water that otherwise would blow away. Takota has installed temporary snow fence at the top of the property to help trap snow as an interim measure while the trees get tall enough. Using information from the Permaculture Designer's Manual and Alberta Agriculture, he plans for the shelterbelts to provide wind protection for 20x its height downhill. By planting on higher ridgelines, he also forces the air to move upward which increases the chance of precipitation.

Currently and for the past many years, their main source of on-farm income is selling small square bales to horse stables. Because of their no-input management for many years, the yields have decreased significantly over the years. The system that they are now putting into place is transitioning them out of the need to be selling the hay.

In addition to hay, they direct market beef, pork, eggs, root vegetables and garlic which are being raised in a market garden-style plot. They also produce a number of things that aren't for sale, including grain, the vegetables from their extensive gardens , most fruits, milk, honey (because of time constraints), and compost. Additionally, Takota is doing educational work as well, including on farm/custom tours, consulting, workshops on different topics (e.g. how to use hand tools), and on farm teaching. He and his father have also been doing construction work off farm but they do less and less each year.

They actively try to promote native pollinators through the diversity of plants, both annual and perennial. By observing they like to gather in groups, they have created habitat in 50 foot zones and made use of the south facing slope. Some of their information has come from Mark Wonneck and his information about ecobuffers. The smallest pollinator insects can travel up to 150 m from their nests, which means that their habitats should be no more than 300 m apart. Takota has tried to accommodate this with the swale design, while leaving enough space for grazing between the tree rows.

Water

They have one well that can pump 2 gallons/minute, which isn't able to keep up with they need. The quality isn't ideal either, having high salt and sulfur. After drilling numerous wells and having several dry up they realized the aquifer would not be able to supply another well on the property. The low water availability made it necessary to put in a dugout but they needed the swale (discussed below) in order to fill it do to the erratic slope of the land. The excellent runoff that they have in the spring (rivers through the top of the property) is very useful in making them work. The lesson is that if you can pick up water from the ditch, road, or creek – take advantage of it!

Originally, there were a lot of sloughs on the land that had been drained from the property. The drainage increased available acres, although the low spots take more time to dry up than would be ideal for conventional management. Under the new system, the wet areas are fenced off and allowed, even encouraged to return to wetlands. As biological reserves they provide moisture for bordering crops and provide emergency grazing for extremely dry years.

For water in the winter, they are thinking about building a deep water dugout close to the house and running their water system off that in addition the existing system. Right now the yard is supplied by a 2 gal/min well (used for winter watering).

They have built a gravity-fed water system that connects the entire farm. The main concept is that there is a dugout at the very top of the property, a dugout at the bottom, and a system of swales and spillways in between. The swales collect and increases infiltration of spring runoff and into the ground. The surplus water which cannot be absorbed by the soil is conveyed on contour to a strategically positioned spillway which either drops the water into the next swale or into the lower dugout. Water is then pumped with a solar pump to the upper dugout which acts as a source of gravity water for watering their compost at the yard, providing fire protection for the house, tree/swale irrigation, and livestock watering. There is a 1 inch plastic pipe placed above the swales for grazing with 500 foot zones of drip irrigation. The gravity water is also set up so there is a watering point every 500 feet for livestock.

Figure 1. Birdhouses mark each watering point every 500 feet in addition to providing habitat.

The lower dugout which was dug only last year is 1 million gallons and 18 feet deep. It was built where the water would have to move through trees to reach it and is surrounded by a ring of trees to reduce evaporation caused by wind – which would otherwise be about 2 feet per year or 100 000 gallons. The location they chose was a naturally wet area with good clay at the bottom. This year he stocked the dugout with 160 trout, placing decoys around to scare away predators. In order to avoid feeding the trout, he has tried to attract insects with light traps, floating grass to attract grasshoppers, and lily pads. The water is kept aerated with a windmill. The water intake is down 18 feet, which should allow them to put in an insulated building to pump water during the winter.

Figure 2. The lower dugout surrounded by brush and trees. The plastic alligator and heron are meant to dissuade unwelcome guests.

The lower dugout also contains a simulated island to attract insects like grasshoppers out onto the water where they are eaten by fish. Excess water is directed back through the property, ultimately towards the creek (see Appendix A). The dugout ended up costing $15,000 which was too expensive – it would have been cheaper to build a longer and narrower dugout. However, even at this price Takota says it was worth it. They now have at least 4 years of water stored at any one time and because of the swale system it is almost guaranteed to fill each year.

Alberta Agriculture Research has stated that you need 150 acres to fill a 1 million gallon dugout. However this spring at least 6 million gallons was harvested from 150 acres. This was because of the tree and snow fence snow traps. As other neighboring farmers cut down their trees to increase their arable acres the resulting increased winter winds speed concentrates snow in drifts anywhere there is something to slow the wind.

Takota is excited about aquaculture (cultivating species like trout, wild rice or colt's foot and possibly freshwater mussels) because it can produce 30-50 times more protein per acre than land. The water remains good quality for livestock and the pond has the potential to keep the fish through the winter.

Figure 3. The upper dugout. Water is collected from the catchment area above as well as being pumped from the lower dugout with a solar pump (there is also a gas pump for backup). The pipes on the right and left can be used to manage the water level and for flood irrigation.

Crops

The 10 acres of the flattest land on the property is where they grow grain for their chickens and pigs. The land is convenient enough to bale graze in the winter in order to maintain long-term fertility. They also use companion planting within their annual grain crop to avoid a pest and disease problems and to increase yields. Currently they are using a wheat/pea/oat/barley mix with an understory of turnips, tillage radish, beets and clovers. All of these plants grow together well. Each has a specific niche and function within the overall crop. For example the peas fix nitrogen but require some kind of support and the wheat, barley and oats, provide a structure for the peas and make use of nitrogen supplied by the peas. The various root crops improve the structure of the soil and together with the clovers are the secondary crop which continues to grow after the grain has been harvested. This understory crop is then harvested by the pigs in the fall. The pigs free range digging up roots and eating any grain that the combine has missed all while fertilizing the land to begin the cycle in the spring

A further 30 acres is for a cover crop grazing system which is an even more diverse mix of annuals and perennials, including wheat, peas, oats, turnips, radishes, fall rye, proso millet, chicory, hairy vetch and sorghum sudangrass.

The perennial pastures have as many different species as possible. They are now mostly timothy, brome, and alfalfa but they are adding in red clover, white clover, sweet clover, sainfoin, cicer milkvetch, and chicory (which is a great forb for cattle). They manage the fields in a rotation so that a different field is left to go to seed and grazed in fall to trample them in order to maintain the seed bank. They would like to have native grasses where possible but their focus so far is on tame grasses which are better suited to rotational management.

The compost is produced by an animal area system and spread mostly above the swales with some on the grain field and garden. Takota hopes that adding compost high to the landscape will passively spread fertility down through the farm.

Cows and Crops

Right now they have 13 cow/calf pairs (including Sophia the milk cow), with 1 herd bull, 8 yearling calves, and 3 two year old feeder steers. Their genetics are mainly Red Angus Hereford with Jersey, Simmental and Galloway. Eventually they would like a 15/15/15 herd which is the carrying capacity of the farm, raised as a closed herd at home.

Figure 4. Sophia the milk cow. Unfortunately no photos were taken of the herd, which we moved to the upper part of the property. Sophia's milk is for personal use as well as increasing the nutritional value of the piglet feed.

The cows are normally moved every day with electric cross fencing, and sometimes twice a day where the water system is well established. Then, every 4 days their water tank is moved to a new watering point and a back fence is installed to prevent them from re grazing where they were the past 4 days. This eliminates any chance of overgrazing. The size of the field depends on the environmental conditions and the time of year.

The cows are grass fed and grass finished with some green feed as part of their diet. Though they bought some hay last year, they would like to grow all of their feed on farm. Their plan with the green feed is to bale it and give the cattle a 50/50 ration mixed with hay in winter. This should happen as a first cut in low areas in order to provide desirable immature seed heads and more digestible straw. After the green feed is cut and baled, the turnips, radishes and beets will continue to grow and again be harvested by either pigs or cattle in the fall.

Pigs

Their pigs are full-blooded Berkshire, of which they have 1 boar and 3 sows. They get 2 litters a year, producing about 35-50 animals per year. Takota notes that 3 or 4 sows are the best complement with their current cow and chicken systems.

The pigs are fed a mix of 65% peas/oats/wheat and 35% second cut hay that are grown and ground on farm. This “chop” is then mixed with milk from their dairy cow and water and allowed to ferment for 12-24 hours. The soaking predigests the chop making the nutrients more bio-available to the pigs' mono gastric digestive system. This dramatically decreases the volume of feed they need to be feed because they are getting more from it. Takota is trying to reduce the amount grain the pigs are fed and encourages them to forage for as much of their own food as possible. He has been feeding them half of what he did over the winter (1.5 lbs twice a day vs. 3 lbs). He has found that pigs love thistles and clover, especially thistle roots which he suspects is the equivalent of spicy food for humans. In the winter the pigs are integrated with the cattle bedding area and thus are able to continue to forage throughout the winter months.

Figure 5. The pigs in their enclosure. The young pigs are feed in a “creep” which excludes the older pigs to from stealing their food. This is accomplished by one electric wire set just high enough for the piglets to walk under.

While they were still being kept in the enclosure during the interview, Takota was cutting and bringing grasses and forbs to the pigs twice daily. However, once the grain crop mix is harvested they will be put out on the crop field to graze turnips and radishes.

Chickens

The laying hens are moved weekly using an egg-mobile and kept on pasture/forest gardens enclosed in electric net fence. They are rotated through the lower forest garden, which provides sheltered habitat for the chickens, manure and dethatching for the trees.

Figure 5. Exterior and roosting boxes for the laying hens.

The baby chicks are sheltered and raised in a coop next to the cow shelter. They start free-ranging during the day once they are less vulnerable to predators, but return into the coop for protection during the night. Being close to the garden, cow enclosure, and pigs makes it convenient to use them as a tool, especially for digging grubs and larva out of the cow pats and to provide various functions in the garden.

Figure 6. Chicken coop and chickens just right of the cow area.

Species Enclosure System

Takota has built an interesting enclosure system that mostly houses the pigs, chickens, and cows over the winter. It is located relatively close to the house so it is easier to manage.

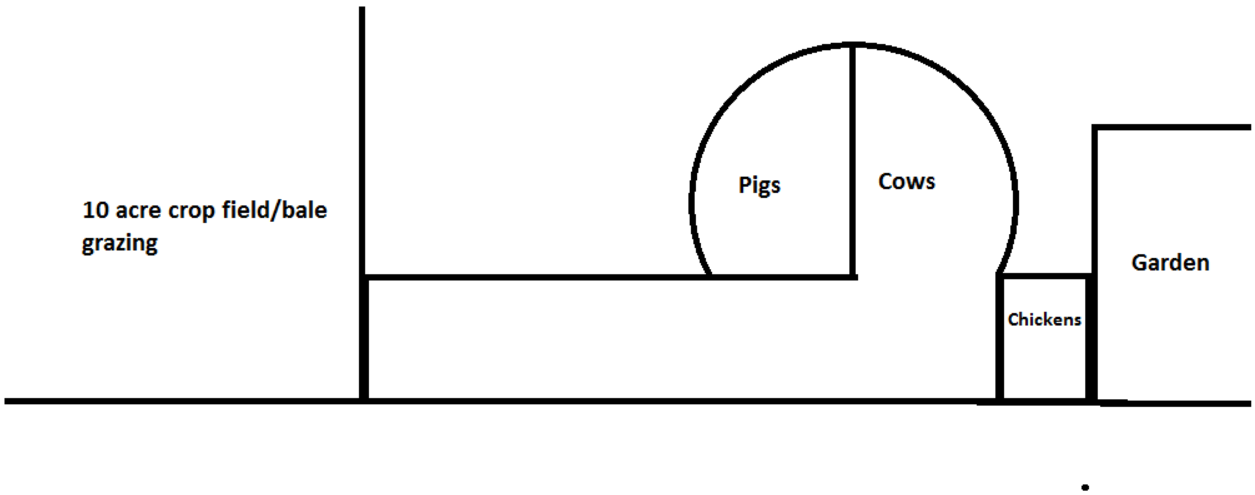


Figure 7. Basic plan of the enclosure system. There are also plans to build a greenhouse and barn adjacent to the chicken coop in the future.

The pig and cow areas are connected via corridor to the crop field, where it is easy to set up bale grazing for winter feed or cover crop grazing. The areas are also connected so that the pigs have access to the cow side (but not the reverse) which lets them root through the cattle bedding area, which keeps the beds clean of manure. This saves approximately 45 minutes of human labor per day. The chickens also have access for the same purpose. This provides a dual benefit of providing more food for the pigs and chickens, as well as interrupting pest cycles associated with keeping livestock so close together (especially lice). The system is located next to the market garden, enabling Takota to use the pigs and chickens to disturb the soil and manage the weeds.

Garden

The home garden and small market garden is a system unto itself, where Takota applies the concepts of low till and mulch gardening. The tillage in the garden system is done once in order to prepare the seed bed rather than killing weeds. Takota has found that mulch gardening has produced excellent results when growing garlic, removing the bare soil that provides a good habitat for weeds and then letting him mow between the rows. At the time of the interview he expected that he would grow $6,000-$7,000 worth of garlic with a total of 5 or 6 days of work.


Figure 8. Mulched garlic in the market garden pictured left. A cover crop is being grown to the left of the plot. Right: one of the home garden plots.

Figure 9. Takota also experiments with different trees and growing strategies near the house. This is a mulched apple tree surrounded by comfrey, a popular plant among the Permaculture community for its ability to provide an abundance of mulch high in potassium.

Tree System

Probably the most involved part of the farm design is the series of forest gardens. Currently there are three main ones: one located next to the entrance road, one mixed with a series of hand-dug swales, and one planted below the main swale running across the property. Trees have also been planted along the most recent swale at the top of the property.

The trees are planted to eventually become a very low maintenance and perennial source of food, in addition to the multitude of ecological benefits that trees provide, including shade, shelter from wind and sun, increased probability of precipitation, habitat for insects and birds, bringing up nutrients and water from deeper in the soil profile, slope stabilization and protection from erosion. They also help to shape the microclimate of the farm, which in turn gives them a greater number of options in terms of what's possible to grow.

Figure 10. The ground level forest garden next to the road. Most of the trees were originally planted as a shelterbelt using species from PFRA. Takota is now using some as shelter to grow food producing species.

Figure 11. Korean nut pine sheltering under a spruce pictured left. The pine is susceptible to sun scald so is located on the northeastern side to prevent it from warming too early in the season. On the right, a black walnut is mulched using cut grass adjacent.

Figure 12. A nitrogen-fixing living fence consisting of buffaloberry, sea buckthorn, and caragana. They also provide edible fruit that can be harvested or used as feed.

The second forest garden is planted on micro swales (which were dug by hand). Like many other areas of the farm, Takota bought as many varieties as possible to test them all out. One of the main issues he has had has been with susceptibility to sunscald. In late winter and early spring, the warmer sun allows the trees to start moving sap which then freezes and expands when temperatures cool down at night. He has noticed that the apple variety “Prairie Magic” is extremely susceptible as well as pears and apricots, but that his plums have done quite well. For this planting he spent between $6000 and $7000 for 70+ fruit trees. Since then he has ordered directly from the nursery which costs around $30/tree and has translated $10,000 in to 1000 trees and shrubs for the planting on the main swale.

Figure 13. Apple tree affected by sun scald.

Figure 14. The second forest garden planted on the micro-swales.

The four 6 inch tall swales are completely on contour, and were able to absorb 6000 gallons/hour for three days straight of snowmelt. Some soil absorption tests they have done have shown that it takes 45 seconds for an inch of infiltration which compares well to the 100 year rainfall of event of 4 inches within 24 hours. He's noticed that the swales (particularly the smaller ones) break down and erode (i.e. fill in) after a few years.

The central swale also has a forest garden design with canopy every 50 feet and understory in five 50 foot rows. This is to force pests to move 50 feet between plants and for ease of management. Both pollination and pollinator habitat as well as the time of harvest have been planned into the design, which took about 6 months of really thinking about how to do it. Here he has planted 2000 trees including 1000 fruiting trees and berries, 500 support plants, 500 hazelnuts, with 38 varieties and 9 genres of plants. For a non-comprehensive list of species and varieties refer to Appendix B.

Figure 15. Views of the main swale with forest garden design below.

Takota has planted 5 rows of trees that make up a diverse forest garden. The top and bottom rows on the slope are hazelnuts 10 feet apart, as climax plants in between sacrificial nitrogen fixers. One row of hazelnuts and N-fixers have been planted above the swale to protect the lower zones, catch snow and one below the swales and other tree crops to provide wind protection. The interior three rows are a mixture of the other perennial fruit and nut crops found in Appendix A. This forest garden follows the 1.5 km middle swale. Furthermore, Takota has enhanced several natural valleys along the swale creating a series of settlement ponds to help filter out the water coming from the neighboring farmer. He has planted some aquatic reeds to further filter it before it reaches the spillway. Below the spillway he wanted more water tolerant plants like black walnut, bur oak and gooseberry.

His general planting strategy is to plant the trees and shrubs much too close together, letting them space themselves out, sacrificing certain ones (especially caragana) over time to the fruit trees, with the intention of taking 3 years for them to become a useful shelterbelt instead of 10.

To help establish the trees, Takota mulches extensively (with an understory of strawberries). The main mulch he uses is hay which is dumped out by a bale processor in a windrow. This windrow is then placed around each individual plant 10" deep by hand. Takota has found that mulching directly around his hazelnuts but allowing the grass to grow around it creates a halo that protects them from wind and deer.

Figure 16. Different mulched species. The hazelnut is difficult to make out in the left picture.

His rationale here is to build the soil organic matter up as much as possible in order to store as much water as possible – rather than spending $5,000 - $10,000 on a million gallon dugout, you can hold as much water in the top 12 inches of soil with 4.5% organic matter on 12 acres. He pointed out that in Australia that the swales often result in springs developing and has been digging test holes to monitor the water levels.

He has experimented with plastic mulch, which works great if it doesn't get holes, but between deer, planting, and getting torn in addition to the higher cost, the fact that it doesn't feed the soil, and doesn't break down, finds that hay mulching works better for him. Mulching with hay also offers the option of spot mulching with small bales by hand. In order to continue mulching after establishment, he has been using a mower with a side discharger.

An interesting feature of the swale areas is the red clover (*Trifolium pratense*) sown in between the trees (see figure 14). This is partly for the more common reasons of keeping the ground completely shaded and fixing nitrogen, but also the hairiness of the plants is meant to increase surface area to catch condensation out of the air. Early in the 2015 season, they had big mists which created micro-weather on the site. Between the swales, Takota mows with a sickle mower or a scythe before a rain to create a sheet mulch that helps trap water and adds fertility to the soil. With this system, they have found earthworms on the soil surface after 2 months of -30°C buried under 3 feet of snow.

As they become established, the forest gardens will continue to operate as a CSA U-pick, managed by Takota, where you can pay a subscription and are entitled to a percentage of the crop (for example). Though they decided against making the system amenable to mechanical harvesting, it has been designed to have groups of plants ripening at the same time from June 21st onwards (e.g. apples in

September and hazelnuts in October). The diversity would protect against crop failures in any particular species. There would still be the potential for someone else to build a business creating value added tree-based products and chickens and pigs would still be a part of the system. Takota plans to start bringing chickens into the system once they become more established.

Swales

Author's note: Swales are potentially the most key component to the farm plan, but they aren't yet widely discussed in the agricultural community. Not appropriate for all environments, basically they are trenches dug on topographical contour, with the spoil piled into a berm below. The purpose is to slow runoff water and allow it to infiltrate into the soil rather than leaving the property and causing erosion. Typically (as in Takota's case) they are associated with trees, which stabilize the berms while having access to the increased water.

The first step in building a swale is deciding where to put a swale and why you're building it. Detailed maps are essential for the process, with the best being LIDAR maps (accurate to 12 inches) – which cost $1,500 per quarter. For the first swale, Takota chose the longest contour line that cut all the way across the property. Two of his considerations were that he wanted to take advantage of the low flat spots above the planned swale to back up lots of water and that he wanted an inexpensive place to build a dam. In Alberta (and Western Canada), the first swale is really dictated by where there is runoff (especially in spring). Depth is another consideration, where the factors are how much water you expect to catch as well as elevation on the property.

In order to build a dam (e.g. the upper dugout), you simply need to dig a hole, pile up then compact the spoil although site selection is important to minimize the amount you need to dig. You then should be able to elevate the water above grade with swivel pipes.

Though swale planning and building owes a great deal to Keyline design and cultivation, Takota has found that keypoints in the landscape are only necessary if you're following a Keyline plowing pattern. Unfortunately, pursuing Keyline cultivation is difficult on small lands or catchments because you can't effectively take advantage of big lines in the landscape (compared to large grazing properties in Australia where Keyline was developed).

The second step is to lay out the line with a laser or water level, put flags in, dig, and then flood it with water to check. When planning to do flood irrigation, the level has to be exact. The process of putting together a swale with trees involves first laying out the swale and having a planting plan on paper (which will make getting help much easier), then building it. The swales are laid out in succession so that if one fails there is a backup plan to deal with the water. In terms of financial cost, the main swale across the property (more than 1.5 km) took 4 hours and cost $700 to dig/build with a D3 Caterpillar (at $115/hr plus trucking fees). The top swale cost under $2,000 for 500 m (larger) and affects 160 acres on the property.

Figure 17. Ensuring the level is accurate during construction of the top swale (photo courtesy of Takota Coen).

The third step was to seed immediately with a mix of annuals and perennial legumes, two or three times. Once the swale is seeded, use a bale processor to put down hay over top. For the most recent swale, he used five 1000 pound bales to cover 450 m plus the 50-60 meters for the dam wall. Hand seeding/broadcasting directly into the mulch is an option.

Figure 18. Takota giving a measure of scale in the top swale pictured left. On right, bale processor covering the swale with mulch (photo courtesy of Takota Coen).

Finally, Takota planted trees into the most recent swale and then flood irrigated it with the dam and upper dugout that were just built. However, without water to flood irrigate you might need to wait for spring runoff, significant rain, or some other form of irrigation (e.g. drip irrigation). The trees also get more mulch, which you can either put down first and plant directly into or put it to the side and spread it by hand.

A problem that has arisen is that melting water has refrozen in the swales, creating ice dams that didn't thaw and had to be chiseled out. Takota thinks that having two spillway levels would help deal with the issue, or alternatively that you could put a pipe in a low spot in order to let the water go and keep it from freezing. He has also had some struggles with how to seed the swales: it is easy to seed in the low spots compared to the high and dry upper side. Going into the future, it might be necessary to seed more to get a better catch and it's important to continue to mulch to trees until they're well established, if a bit less than the initial establishment.

Risk Management

In order to manage financial risk, they don't have crop insurance which promotes poorly designed systems. Instead, they insure themselves through their CSA customers who are willing to work with the realities of the farm such as accepting a bad turnout out pork this year. Another avenue is personal loans, where the loaner wants to them to succeed and is willing to work with them to make it fair.

Functional redundancy and multifunctionality is everywhere on the farm. First are the diversity of yields which provides choice in what to eat and sell. They also can choose how to use the yields – the milk can go to the pigs, chickens, calves, or be used as a foliar spray; apples and grasses can go to different animals; the green feed can be stacked with the cows using some, pigs eating the leftovers, followed in turn by chickens, and the final residue can be added to the fish pond. By providing a diverse habitat as an alternative to hand-pollination, they have a redundancy of pollinators which includes honeybees, mason bees, leaf cutters, birds, butterflies and bats. The space they have is also flexible, particularly the 10 acre field which could just grow grain, grain and a legume, or an understory of turnips and beets which can be sold or used as feed, offering options for different rotations and event timings.

There are also several infrastructure redundancies. While the livestock area system had a fixed area cost, it allowed them to put many animals together in a place that could conveniently produce compost. The water pipe built on the swale has the potential to either water the trees through drip irrigation or provide water for the livestock. Even the fences can be used for growing trees, fencing animals, and as birdhouse supports. The garage is used to fix machinery, build projects, process animals, and as teaching space.

Takota is surprised at how well the system handles stress and how fast things bounce back, including how quickly the first swale was established and how fast the garden soil or pastures come back after grazing. After a big storm in 2014, their wheat lodged and poplars were blown down but two days later they had picked themselves up again (they were about 5.5 feet tall).

Yields and Enterprise Importance

Yields

Their yields for a wheat/pea intercrop are 40 bu/ac and their oat yield was recently 60-70 bu/ac. Their pasture used to produce 100 bales/ac (1st cut) and 40-50 for the second, but now it's 40-50 bales/ac for one cut per year. Takota expects that their management will start to increase yields again – last year they produced 40-50 bales/ac which grew back well and instead of haying it a second time they got another 2-3 weeks of grazing and left a good amount of litter. He expected to produce 50-60 bales/ac this year (although this may have been affected by the drought). Ultimately he would like to be producing 10,000 lbs/ac of biomass by increasing organic matter. In order to bring up the organic matter, the management will be to graze instead of baling and taking a 1/3 while leaving 2/3 of the material on the land. While this used to be considered waste, he believes that the more you put back on the land, the more it produces. The first year pasture land above the swale was looking good and was going to be grazed lightly. They have found that the oat green manure has really benefited the pasture above the swale.

They have good growth rates on their cattle, which dressed at 900 lbs last year. Takota is very happy with the pigs, which grew to market weight in 7 months at full feed. Since they are now being fed less they should take more time to grow.

Their yield volume is much less than conventional but they have higher nutrient density and quality, which allows them to feed their pigs less. Takota compared their meat quality with the Hutterites', which they've seen has growths and tumors and gray spots running through their pork, resulting in oily and smelly meat. The Hutterite pig diet after weaning consists of canola meal (straight protein and fat) and soy (difficult to digest) meal as well as canola oil. Two customers have said that their pork tastes like hog barns and that they couldn't eat pork because it makes them sick – which isn't the case with Takota's pork.

More generally, people aren't satisfied by their food nutritionally so they tend to overeat high sugar foods which don't have any natural taste. Furthermore, conventional yields are deceiving in that they don't take into account nutrient density or the energy return on investment (EROI), in that they require large amounts of material and energetic inputs to get those high yields.

For the crops they grow for themselves, they only use a little bit of compost and irrigation (no fertilizer). They grow more raspberries than they can handle, and their cherry trees are looking good for the first time this year. Some of the older apple trees are starting to produce: they've gotten 25 gallons from one small tree. Overall, these yields give a great return for the work they put into them.

They're very happy with their home garden yields, which are relatively low maintenance. Garlic, which can be challenging to grow, has produced very well for them and it hasn't had any disease pressure even in wet years. Their only problem was that they didn't dry it sufficiently and had some mold.

Importance of Enterprises

As the system develops they save more and more cash. For example they no longer have to buy grain as feed anymore.

They are selling 21 dozen eggs a week at $5/dozen which totals $5,500 and it is set to double this fall and into next year. The pork produces a $10,000 gross income from the first batch of piglets. With their beef, last year they made $7,500 with three animals which they are set to sell again. In the following the years they expect 8 and then 13 which will allow them to farm full time. His parents make $25-30,000/yr by selling hay. He expects about $5,000 from the garlic in addition to keeping enough to grow it again next year, which should end up averaging between $5,000 and $10,000. The pork should ultimately produce $20,000 to $30,000. Neither pork nor garlic involve much in the way of production expenses. The CSA farm shares come to $9,000 over four years in the form of presold farm products.

The wild card is the forest garden, which will have a very low maintenance cost now that the system has been set up. The watering system makes it extremely easy to water the trees and move the cattle around the property. There is a good chance that they will be able make the rest of their living here, whether it's in the form of value added products or managing a U-pick. The earthworks workshop that they held in spring 2015 helped to offset the cost of the solar pump that moves water from the dugout at the bottom of the property to the dam at the top.

The money that Takota makes through his educational work and Deep Roots Design is directed into other systems in order to help support other people.

Inputs and Labor

The farm inputs are fuel, seed (mainly grass and clover), trees, and certified organic livestock mineral. They also bought rock phosphate 20 years ago.

For labor, there are 3 people working full time which can be translated into 6 full-time positions plus off-farm work although this is seasonal like most farms. In hour terms, it is 12 hours a day for 4 to 5 months (although the work itself isn't that hard most of the time) while winter hours are closer to 1.5-2 hours/person/day for chores. Takota's brothers and sisters often help move cows and help with big jobs like planting trees or mulching depending on the time of year. Takota is expecting to develop an apprenticeship program for education – several interns would pay to come and learn how to manage the farm, allowing them to start their own operations.

Infrastructure and Equipment

The infrastructure they have on the farm includes the straw bale house, a conventionally framed and heated garage with living space, a large open air hay shed/machine shed (which could store a number of other things as well), several small storage sheds, livestock fences and corrals, the chicken tractor setup, chicken coop, three 100 bushel feed bins, and four 1200 bushel granaries.

The equipment they have includes a 65 hp John Deere tractor without a cab with a loader, a 100 hp 1969 open station 100 hp John Deere tractor, and a 23 hp Kubota garden tractor with a mower, 3 point hitch, and rototiller. Their haying equipment includes small square balers, and a stack liner/bale picker. They have some modest tillage equipment (disks and plows), a swather, an old pull-type combine, two 22 foot car hauler trailers, a 14 foot aluminum stock trailer, a 12 foot double disk end wheel seed drill, and two trucks. They also have a $2,500 mixer mill that grinds all the feed on farm which has a bale processor to add bales into the feed.

They have some well-built root cellars for vegetable storage, and 5 deep freezes as well as their kitchen fridge. Most of their outputs are sold before they become outputs, with lots of planning and communication to avoid potential issues (e.g. if someone goes on vacation). It helps a lot to be a people person and orchestrating their output sales should be a full time job.

Figure 19. Seed Cleaner pictured left. Root cellar pictured right. The root cellar shed is built on top of a six foot diameter vertical culvert dug into the earth. This cellar stores thousands of pounds of root veggies up to 8 months in perfect condition.

Interestingly, Takota sees their pork as storage in a sense – taking in grain, potato and milk and transforming it into something that is easier to sell. Choosing crops with easy storage needs is another consideration. Garlic is useful because it just needs to be cured then kept dry and will keep for 8 months at room temperature. With a relatively high value per pound (Takota is able to sell it for $10-15/lb), it compares well with asparagus which has a shelf life of about one day.

Environment

Weeds and Pests

The insect problems that they have consist of mosquitoes (which were surprisingly bad in the low parts of the property considering the dry spring) and cabbage moths which has kept cabbage out of the garden. They have treated their cattle with diatomaceous earth for lice in spring but there hasn't been any this winter. Takota thinks this is because of their integration with pigs cleaning out their wintering area regularly and that the chickens will help clean it better during the coming winter. Many of the birds eat tree pests and flies that bother their cows as well.

They have only lost a few animals to coyotes: they haven't had many problems since they shot one that ate a calf and put it up on the hill as an example. Foxes have taken some chickens, but this is manageable with good pens, having a dog, and not encouraging them to visit. In order to maintain the hawk population to manage their gophers, they need to make sure that the wild areas have enough abundance so they don't start hunting for chicks.

Their main weeds are absinthe wormwood and toad flax. In contrast to most others, Takota sees weeds as an indicator species that shows that something is wrong in the system. With that said, the problem with the wormwood is simply that it's too prevalent: Mark Wonneck has put it into his ecobuffers because it is a great pollinator species. Having a diversity of weeds in the system putting exudates into the soil is great for many of the beneficial soil organisms living there as well.

Ecosystem Services

Many of the components of the farm offer distinct ecosystem services. The swales, while artificial, offer a host of benefits, including slowing, spreading, and sinking water into the soil, cleaning the water, spreading fertility, providing microclimates for pollinators, affects one moves through the landscape (on contour vs. moving up and down), absorbing water from the compacted road area above the swale, creating a moist environment for trees, and eventually producing springs that buffer against floods and droughts. They also can catch a lot of organic matter, particularly leaves falling off the trees above which create a natural mulch. The sediment ponds designed into the swale system help to keep the water clean.

The trees (planted and wild) catch snow for more moisture, they attract wildlife and birds (which brings additional fertility), offer wind protection, and microclimate production. A neat potential benefit is that they can catch nutrients in the wind by slowing air speed and causing the dust to drop out. Considering that an acceptable loss of soil due to wind erosion is 3-4 tons/ac/yr, this may not be an insignificant source of fertility. They also help manage the water regime, bringing up water from the subsoil with tap roots and letting it out to the hair roots and pumping water back into the ground when conditions are wet.

The presence of the animals in the system enhances nutrient cycling by speeding up the break up process of plant material. As more types are brought and integrated into the system, there is a marked improvement. Chickens (which are excellent at picking out weed seeds) and pigs (which cleaned out a 'quack grass pasture') do very well at breaking up disease and weed cycles. Chickens are also helpful at promoting tree growth by congregating under them, dethatching the grass (minimizing competition and increasing water infiltration) and dropping nutrients. In exchange the trees provide shelter and some food which allows both components to benefit.

Direct Benefits

There are a number of benefits that the bush areas offer, including 150 lbs of wild saskatoons (a particularly valued and reliable staple winter fruit), pollen for the honeybees (from the willows and poplars), firewood from woodlots for fire places, deer hunting potential, medicinal plants and wintertime herbs. They also have mushrooms like oyster mushrooms (which have been seen but not eaten) and Artist's Conch (*Ganoderma applanatum*) which has medicinal properties. The forest areas act as biological reservoirs that act as an inoculant to recolonize disturbed areas as well. They have noticed that the wind protection from their bush areas makes it so that the outside parts of the fields take longer to dry.

Figure 20. Artist's conch on left. Creek leading off the property surrounded by natural bush on right.

Red-tailed Hawks are a good control on their gophers, but the gophers themselves offer some benefits. While they still will shoot gophers when they encroach on the garden, the gophers are valued for enhanced water infiltration, soil conditioning and subsoiling, adding fertility to the ground, and (may) increase the chance of rain. Takota related a Bill Mollison story about natives in the Sonoran desert who told the colonists that if they killed the prairie dogs there would be nobody to cry for rain – and the region has been dry since then. The rationale for the story is that gravity from the moon pulls negative ions out of the holes which increase the chance of rain.

Biodiversity and Wildlife

There is a variety of wildlife that lives and passes through the farm, including deer (mule and whitetail), moose, rabbits, foxes, coyotes, weasels, gophers and badgers. There are no beavers anymore: they left after the sloughs were drained, however a muskrat has been spotted in their new dugout. They have not been seen for 20 years. There are a number of bird species on the farm as well, including sparrows, hawks and tree swallows. Takota tries to encourage the hawks to nest in the area because they act as their main gopher control, with one nest consuming as many as 500 gophers a year. The hawks used to be a problem for the chicks 2 years ago. However, as a solution the chicks are now locked up (with supplemental grass) for their first three weeks and don't go outside until they're safe. Takota speculates that the nearby pigs help to keep the hawks away.

Beneficial small creatures include dung beetles, butterflies, earthworms, and native pollinators. Takota has noticed two kinds of dung beetles in the manure, which bore holes 2 feet into the ground. In the 2nd year of rotational grazing, he's found that cow pies deposited in spring tend to disappear by the fall. Bumblebees are especially valued because they're much more efficient at pollinating than honeybees. Takota has found that 2 years after planting trees in the swale he is finding earthworms in every hole he digs.

Overall, Takota gives them an A+ for environmental performance. Their system is largely self-fertilizing, waters itself for the most part, and most of their perennials would keep growing without any more assistance (although most of the trees wouldn't grow as fast if they weren't mulched). They have abundant and diverse pollinators and a number of bird species are returning to the farm. Their soil ecosystem is performing well and they don't have any problems with bad insects. They are pretty happy with their wildlife populations too.

Figure 21. Bumblebee on raspberry bush. The bushes near the house all had a very large number of bees and insects.

Advantages and Challenges

There are a number of things that have allowed Takota to create the system that he has. First of all, having parents with the machinery, knowledge, and willingness to help have been essential. His independence, both when it comes to not having a family to support and being able to live at home with his parents, have given him the opportunity to spend a huge amount of time learning and planning. His character is also an advantage, partly in his willingness to make mistakes and his personality, but also his commitment to making the system work. In order to finance a lot of what he's accomplished, he sold his construction equipment (including his truck) and invested it (and his personal savings) into the farm. The support from the community has been helpful as well: his parents are well respected and have a lot of moral and social capital. The trust that they have has made it much easier to find CSA members. It was possible to raise much more than the initial $9000 but Takota was not comfortable with that level of responsibility to people he had never met.

Takota observed that he would have much less freedom to do most of the things he has with the burden of land rent or a mortgage.

One of the advantages of the farm is that it is located on a south-facing slope, which (according to Martin Crawford in *Creating a Forest Garden*) creates a microclimate that helps miss the first and last two frosts of the year. In grazing terms, there are an extra 2 days of grazing for every degree of south-facing slope, which on the Coen's land with a 0° to 20˚ slope affords them up to 40 extra frost free days. This has indeed been observed at certain locations.

The main challenge is figuring out what types of ecological techniques work here – most of the techniques have been invented and adapted in other places but haven't been applied in the Western Canadian climate. He is fairly confident that he's mostly overcome this hurdle at this point after lots of trial and error.

The other major challenge is overcoming the barriers presented by the larger cultural and societal paradigms. Simply doing something radically different is a challenge in and of itself.

Social

In terms of social support, Takota's immediate family is very supportive with his siblings helping to plant and weed the trees. He is partnered with is parents who are a huge support and act as a symbiotic feedback for his many projects. Another farmer (also interviewed), Don Ruzicka, is extremely supportive and in spending lots of time at Augustana University he has made friends with students and professors. Takota credits his parents with helping make the farm successful as well as the community that he's helping to build.

There isn't much support from farming relatives that have a very different world outlook and approach to farming.

Motivation and Concerns

Takota was initially motivated by the realization that the way they were farming was not sustainable by definition. He continues to be motivated by an ethical and moral responsibility to farm the way he does. It gives him a feeling of connection and compassion with the rest of the world – a sense of belonging. Also they really like to eat good food.

His epiphany happened about 4 or so years ago and came out of asking about and investigating different ways to farm. 2.5 years ago he decided that Permaculture and ecologically designed systems were the way he wants to do it.

Getting away from annual grains is one of Takota's priorities. An example of a substitute is the Bur Oak (*Quercus macrocarpa*) which has a high concentration of carbohydrates, is native to Alberta, tastes like wheat, and has a sweet acorn unlike others that need tannin leaching.

His biggest concern for the future is the wild card of political and economic instability with their implications for the food system. It is going to be the easiest to transition to a more secure form of agricultural production now but our leaders refuse to acknowledge the underlying problems and risks in the system. There will come a time when we no longer have a choice to adapt. The possibility that the agricultural system will collapse makes Takota worry that governments might annex the only good land that's left.

Learning

Sources

The list of techniques and ideas that have influenced and shaped Takota's approach includes Permaculture, forest gardening and agroforestry, perennial polyculture Keyline Design and Contouring, grass finished and free range animals, Integrated Livestock Management, Integrated Pest Management (e.g. leaving space for birds) and cover cropping. His approach to cover cropping is slightly different than a more conventional approach, being focused on companion/community planting and how we can plant more plants that grow well together (e.g. wheat and peas) and understanding the cycles and timing of planting (e.g. adding squash into a green manure).

Takota has done most of his learning through online research. He likes to hear and see things, so he's watched many videos of farmers who might not have the same farm but have excellent systems in place. He has also done some reading of books and references (I suspect more than he thinks he has). He likes to see if someone has tried an idea first, but a lot of his learning has come from pure trial and error as well.

On a personal level, he's learned a great deal from the practical experience of his parents and talking with farmers on field days – particularly with Don Ruzicka. He has taken two Permaculture Design Courses, done workshops with Mark Shepard, and taken Elaine Ingham's Soil Food Web course. Elaine Ingham has been a strong influence on Takota, with her view that a healthy soil has no need of additional fertility (so long as you keep feeding it with mulch).

Desire to Learn

There haven't been many things that he's seriously considered and not tried. However, there are quite a few ideas that he's keen to pursue in the future. At the top of the list is introducing a new type of grazing animal which will likely be sheep, and how to develop aquaculture on the farm (even though he doesn't have the time). In order to capitalize on the extra water from the swale he's also thinking about wild rice production and cattails. Lower on the list are starting a small-scale dairy, building a greenhouse to start trees, a market garden, and finding new fruits to try. When it comes to setting priorities it's most important to start with things that will make other things easier which in their case was designing and building the gravity based swale and dugout watering system. When they were running on well water they could irrigate 500 feet of 1 row at once and now they can do 500 feet of 3 rows simultaneously.

Because of the large amount of water that he's been able to harvest in the first year, Takota expects that he will be able to build dams with swivel pipes in order to control the water levels at the low point of the property. This water and ability to flood irrigate would give him the options of growing half an acre of wild rice, having an area of cattails (which have huge root and vegetation biomass that can be used at minimum to help feed the pigs), or even to start raising fish.

He is currently looking seriously at aquaculture, partly as an alternative protein source and partly because processing is much more lenient than terrestrial animals. Another concept he's working to apply is pasture cropping: seeding annuals into a perennial pasture. So far his experiments haven't worked but he expects to spend more time thinking and planning to solve some of that system's challenges.

While they don't pay much attention to solving pest or disease problems, Takota is curious about more specific research into the physiology of weak and inbred honeybees. He's quite interested in understanding more about soil health and the soil food web and especially how elements can interact with each other.

Being able to slaughter the animals on the farm would offer several advantages, including easier transportation, and composting the waste in order to maintain a tighter nutrient cycle. They are also somewhat uncomfortable with current conditions for their animals in the last 24 hours of their lives - they don't get to see the animals and there can be poor conditions for the animals. Eventually they would like to be a part of a meat share program or have access to a mobile slaughterhouse, which could kill, chill, and take it to a butcher of their choice while keeping the guts and skins on the farm for composting.

An idea that Takota is quite interested in is that of Alnoculture, which is growing annual crops under alder trees. He is wondering about adapting it to plant hedgerows of caragana (which are controlled by mowing and wheat harvesting), using a perennial system to back up the annual.

He is also still working on the cover crop system, trying to figure out how to incorporate different timings of grazing, chopping and mulching, and cover crop planting in order to keep plants from going to seed while building the soil.

Lessons Learned

Overall he's learned a ton in the last 3 or 4 years. One of the big lessons is that drudgery is punishment for stupidity: if you have too much going on you can't enjoy what you're doing. It's also very beneficial if you can rely on people who like doing things you don't like to do. You can't do everything by yourself and it's usually more efficient to get help if you can. He's also learned that he and others have limits and that it's necessary to respect them.

Another thing Takota is very interested in is variety trials and looking for genetics that are well adapted to the farm. For example, he has looked at heritage varieties of wheat side by side: red fife which performed very well, and emmer wheat which did terribly. After doing these trials, you have the option of either fixing your soils to accommodate a species or variety or finding crops or animals that work well for your site.

Looking back, he notes that a lot of components that he's struggled with have started to come together. He could probably have benefitted from doing more hands on research or apprenticing on other farms, although he wasn't finding the type of system that he wanted to see in their area. Along the same lines, he might have started a little bit smaller than he did in order to prepare and develop the land and swales a little bit better before planting the trees but he was very anxious to get the system going.

Takota has found that the Keyline practice of subsoiling (plowing deep in the soil to break up compacted layers and exposing lower soil horizons to the air) is a mistake in Central Alberta. With an on-farm trial of multiple subsoil plowing strategies, he hasn't noticed any differences. Its main function (breaking up compaction) is simply not an issue, especially with the freeze-thaw cycles that break up compaction layers naturally. The cost (in terms of horsepower and fuel needed) is much greater than building swales on the property.

He has performed green manure experiment on the field from the creek to the tree line on the main swale. Oats were seeded and in year one they were either tilled, left standing, or taken for feed/hay. He found in the second year that the growth was double where the oats had been tilled in. The lesson he learned was that giving organic matter back to the soil can make incredible improvements in one growing season.

If he had to reestablish everything, he would build the swale and let the water level (and soil quality) increase for a year or two before planting the trees. As it was, he pumped water from the bottom of the property up into the swales for 3 days, moving about 60,000 gallons per day with 4gallons of fuel. Another thing is that he might have made the swales bigger to allow for more water capacity and reduce chances of over flow.

Theory

In order to improve the ecosystem, it is important to be aware of fertility cycling and natural succession processes. Working with fertility cycling is a way to build up a site without bringing in external inputs. Putting clover in the swales, oats in the garden, and planting trees with the intention of cutting them back and ultimately sacrificing them are all examples of speeding up natural soil building processes. When it comes to succession, one needs to understand the climax community that the system will naturally strive towards in your biome, as well as the different stages of succession on the way there. One of the advantages of building ecosystems is that at some point they begin to affect their own climate, allowing you to bend the rules for what you can get away with. Trees and forests are the main example here, largely self-maintaining by affecting wind patterns, moderating temperatures, soaking up excess water but preventing excessive loss during dry spells.

In order to apply the techniques, and make food ecosystems work more efficiently, you need both plants and animals. The important concept is to focus on having a greater diversity of *connections* between elements rather than just having lots of diverse elements. For example, the Hutterites have very diverse enterprises but very few connections between them. In order to do create more connections, know what your elements need and what they do, then tie them into other elements in such a way as to make them do work for you.

Once you have something that works, you can also keep it going in order to slowly adapt it over time for the environmental conditions and people living there. All of their stock originally came from one Jersey cow and over time they gradually brought new genetics in, developing great finishing qualities and a high quality of meat. While they are happy with their pigs and cows, they are looking for a good breed of chickens that they can eventually breed and adapt to the farm. Although this is mostly a future project, this year they hatched 12 of their own chickens (which were allowed to hatch on their own).

Another of Takota's strategies is to experiment with as many varieties as possible, whether they are perennial tree species or varieties of garlic in the garden. However, it is very important to make decisions about what to or not to do, being careful not to take on too much work at once.

An important approach to building the farm system is the idea that fossil fuels are used sustainably so long as they have a planned obsolescence – you want to create systems where you don't NEED fossil energy. This approach lends itself to figuring out how to make the system work with hand tools and dealing with livestock such as cattle. Takota pointed out that growing food for the family would be easy to do by hand.

Philosophy and Observations

Things that Would be Nice

Something that would be extremely beneficial in terms of promoting good water management and swale construction on properties would be for the Prairie Provinces to buy all of the LIDAR data, incorporate it with a GIS application and make it publicly available.

Takota believes that we need a food system where "organic" certification is redundant and that the consumers are the main certifiers through outreach and tours rather than paperwork. On a practical level, they aren't currently certified because they're too small to afford the paperwork and inspections. In the future, he expects that farming systems will be smaller and that farmers will have real relationships with their consumers.

Views on Permaculture

For Takota (and probably many others), Permaculture is the ethical science, study, and conscious functional design of connections between elements. It looks at all the different techniques out there and asks how we can tie things together and not just garden in isolation. Before this he just saw it as a bunch of really cool techniques. He's been particularly inspired by Bill Mollison's phenomenal early works and recordings. Other strong Permaculture influences are Dave Jacke, whose ecological design encompasses societal connections as well, Darren Doherty, and Mark Shepard. Takota pointed out that the proliferation of labels for slightly different Permaculture systems has to do with their ability to copyright and keep big companies from misusing their brand.

Insight into the Status Quo

Takota got in touch with Alberta Agriculture, sending along a plan and videos to pursue fruit variety trials. The reaction to his plan was “why would you bother”? The reason that people grow monocrops, spray, fertilize, and irrigate every year is because it’s easy and that they want simple things that they can control. The result though is that they end up putting themselves through a lot of drudgery and unpleasantness in order to make the system work.

He does find it a bit baffling though why people don’t grow more edible trees since other trees are just as expensive to purchase and establish.

Issues with Organic Production

The family finds that certification was different 27 years ago when his parents started. While there are many good organic farmers, there are also many certified bad ones and the industry is starting to hurt itself by overdoing it. The big positive is that it’s important for transitioning both the land and people's thinking from conventional. It also lets consumers know something about the product. A concern they have about the sustainability of standard organic is rock phosphate (a common fertilizer in organic system) is often contaminated with cadmium and uranium.

Takota was critical of Michael Phillips, who is the author of *The Holistic Orchard: Tree Fruits and Berries the Biological Way*, pointing out that Phillips goes through a ridiculous amount of work to produce an apple. He sees Phillips’ issues stemming mostly from his planting in big blocks/orchards, which ends up creating both fertility and pest problems (all organically). In order to deal with these issues, Phillips produces at least 3 or 4 sprays for multiple purposes which have to be reapplied if it rains and he has to do a lot of pruning to minimize stress on the trees. While he has phenomenal yields, in addition to being a full-time orchardist, he is also a full-time author and still works as a carpenter.

Appendix A - Map

Figure 1. Contour map of the farm. The dam/upper dugout is located with the upper swale in the top left hand corner. The central swale runs along the longest contour line on the property and a third swale has been built lower down closer to the dugout. There are 3kms of swales thus far. Lines perpendicular to the swales indicate spillways to release excess water at points where the slope is gentler. The lowest line indicates the path of excess water coming out of the dugout on the west (left) before looping around the garden and animal enclosure and exiting the property via the creek running just north of the yard. The perpendicular lines on the path of the excess water indicate small dams with adjustable pipes to control the water levels. The goal is to keep as much water on the property as long as possible. The lines in parallel show the location of the second forest garden planted on microswales.

Appendix B - Plant List

Species	Variety	Amount		Species	Variety	Amount
Apple	Battleford	5		Cherry	Evans	35
Apple	Carlos Queen	5		Cherry	Valentine	35
Apple	Dexter Jackson	2		Black Currant	Ben Conan	30
Apple	Harcourt	5		Gooseberry	Hin.Red	30
Apple	Norland	3		Gooseberry	Pixwell	30
Apple	Prairie Magic	3		Currant	Red	30
Apple	Prairie Sensation	3		Black Currant	Ben Sarek	30
Crabapple	Kerr	2		Blueberry	Chippeway	25
Crabapple	Trail	2		Blueberry	N. Country	25
Plum	Brookgold	6		Blueberry	Northsky	25
Plum	Brookred	6		Blueberry	Polaris	25
Plum	Mount Royal	6		Alatus	Dwarf Winged	3
Plum	Pembina	6		Cranberry	Amer Hibush	10
Plum	Toka	6		Cranberry	Amer Wentworth	10
Rose	Theresa Bugnet	10		Walnut	Black	20
Rose	John Cabot	2		Oak	Bur	10
Haskap	Honeybee	50		Fl Crab	Selkirk	3
Haskap	Borealis	50		Delphinium	Blue Fountain	10
Haskap	Indigo Gem	50		Coneflower	Magnus (pu)	5
Haskap	Indigo Treat	50		Poppy	Orient Allegro	16
Haskap	Indigo Yum	50		Sub Creep Phlox	Blue	24
Cherry	Carmine Jewel	35		Polygonatum	Solomons Seal	5
Plum-Cherry	Manor	50		Globeflower	Or. Prince	25
Cherry	Crimson Passion	35		Raspberry	Aubin Black	30
Sour Cherry	Cupid	35		Raspberry	Fall Gold	30
Sour Cherry	Juliette	35		Raspberry	Wyoming Black	30
Cherry	Romeo	35		Grape	Frontenac Red	5

Appendix C - Relevant Video Resources

Forest Garden Video: https://www.youtube.com/watch?v=pnW_1E_EYko

Interactive GIS LiDar Map Application Video: https://www.youtube.com/watch?v=ak7nH0Deu3I

Swales in Action: https://www.youtube.com/watch?v=zxPFOA7WO7M

Grass Roots Family Main Frame Farm Design Video:
https://www.youtube.com/watch?v=CB07zySLPtE

Farm E

Ryan Boyd
Brandon, MB

Background

After growing up on the farm, at 32 Ryan has been farming for his whole life and farming full time for the last 10 years. Even though he was born into it, he's found that he likes the lifestyle and would rather do it than anything else. The year he was deciding to study either engineering or agriculture was one where the harvest was okay (after the bottom of the farm economy in 2001) so he decided on Ag, where he felt he really fit in with the culture.

Ryan began to adopt his worldview and approach to farming after having seeds planted at university and starting during a tough economic year on the farm. He was pushed towards trying to figure out how to live on the farm without too much stress and feel good about what he's doing while still making enough money.

History

Ryan's grandfather's half section was bought in 1945, after the land had been broken for 50-100 years. All five fields had been broken at some point but only two were at the time. Later, his dad started farming in the early 80s after growing up on the farm, who was eager to minimize tillage. After starting minimum till 25 years ago, he began to single pass/zero till seed 15 years ago, using a John Deere 1890 air seeder single disc opener (which is a version of a zero till disc that's been around for 30-40 years).

His grandpa farmed and owned his own fields until 10 years ago, farming with his dad together but separate. Meanwhile, his dad expanded his own operation during the 90s and 2000s. When Ryan started farming in 2005, he bought 5 quarter sections from his dad and formed a partnership and then incorporated together in 2007. Over time Ryan will take control over the farm shares.

Back in 2005, grain prices were very poor and his dad was burnt out and wanted to do something different. He was interested in cattle, which were really cheap at the time. When grain prices went back up again, they were able to learn how to manage livestock without any worries.

Their pastures have been managed organically and their crops conventionally but the farm management has changed quite a bit over the years. Ryan's father was the first to try zero till and one-pass seeding. They have always been a mixed farm raising cow-calf pairs, but when Ryan came back from university they were mostly grain. The poor weather and bad markets that year drove them backwards financially and was a humbling experience. It would have taken them 10 years to dig themselves out of the hole if the next year was that bad so they were motivated to try something different. It was in that year that Ryan came on as a full partner on the farm, which saddled him with a full part of that loss.

At the time, his dad wanted to take on more debt (which might have been the right choice in hindsight), but Ryan's research, travel, and ideas planted by professors Mario Tenuta and Martin Entz had him intrigued in making changes at the farm system level. Also, after growing up sitting in the tractor and driving around feeding cows in the winter, he started to find it too easy (and boring). Thinking about how to make the system work better became more interesting and rewarding. The broad idea that was behind these changes was having a system with low inputs, using cattle to impact the land base and make the farm work.

Environment

The farm is located 10 miles north of Brandon where the 'average' rainfall is 12-15 inches of rain. However, the last two years both had more than 20 inches while at the time of the interview in 2015 (mid-July) it had only rained 3.5. The last frost was at the end of May in 2015, but it will often be in early May while the killing frost typically comes in the third week of September. Their snow moisture can be significant and they try to capture what they can.

The farm is basically windy all the time every day. Zero-till farming helps to prevent wind damage although the crops still do better when sheltered: the best pasture growth is where it's protected by trees.

Environmental Issues

Oil and gas developments affecting the farm are limited to pipelines that create a bump that you bounce over. The chemicals they use may be common practice in the area, but Ryan still worries about them. Of more concern, especially in the last couple of years, has been runoff and erosion. In the spring, the creeks created by the snowmelt (they are normally dry by June) are washing out and are too wet to seed to grass. They cut a bigger trench every year, especially on the rented land. Overall Ryan thinks that they could still stand to be getting more water in their soil. They try to keep their waterways buffered in order to keep livestock-based residue (e.g. from bale grazing) from being carried downstream by the runoff.

Neighbors

There used to be lots of mixed farms in the area, but almost all of them now are based on wheat and canola, with the odd winter wheat and oats. Sometimes flax gets substituted for canola and soybeans are starting to come into the area. For the most part people have been doing pretty well lately with good prices and decent weather. There is little incentive to change, especially with crop insurance as a fall back.

Ryan has seen the bush mostly disappear in the area over 20 years, including a 100 acre forest that's all but disappeared. Most people would rather cut down the bush and drain the wetlands, partly because it's more efficient to farm straight lines and easier to maneuver ever larger equipment, and partly because it costs $500/ac to push down the bush compared to $2,500/ac to buy more land.

Markets and Marketing System

Ryan and his father market conventionally, with spring wheat going to the local elevators and fall rye being sold at Van Dale seeds. They sell their peas for seed for the most part, but they sell some to a broker that markets it as feed for hog rations. Their non-GMO canola goes to the Viterra plant at St. Agathe while their GMO canola goes to an ADM crush plant, either in North Dakota or Yorkton. Their winter wheat gets converted into ethanol in Minnedosa for Husky. They haven't grown flax for a couple of years now but that, like their spring wheat, goes to the local elevator.

To date they haven't had any real issues with market access: it's easy to haul to the elevator and cattle buyers are willing to bid on a call at any time. The only problem was with the rail a couple of years ago because of the massive harvest and oversupply.

They do a little bit of local processing for their own use at the local abattoir in Oak River. There is a one month wait to have anything slaughtered but it's only for themselves, friends or family.

The calves get sent either to Brooks in Alberta to be finished over 90 days, or south to a South Dakota or Nebraska feed lot. They don't yet have enough to sell into the auction as grass fattened (those that do go to a feedlot in Ontario). Their culled cows go to P Quintaine & Son Ltd. and find their way into a kill plant in Alberta or the US.

Direct marketing is something that Ryan is thinking about, but hasn't pursued yet because he isn't confident enough in being able to produce animals with consistent enough quality. He believes that there is a better alternative to the grocery store system, and that consumer demand is starting to move things away from that model. He's excited to start selling a nutrient dense product into the new system even though they aren't there yet.

Social Support

Ryan gets a lot of support from his family: everyone is on board and shares the same goals and vision. His wife might rather he take more time off though because of the long days. Friends and likeminded people are also great to talk to and bounce ideas off of. The network of farmers out there doing similar things helps them avoid repeating mistakes.

The community of neighbors is great as well and lots of people are willing to lend a hand either sorting cows or fixing machinery. Even the people from the city who live on nearby acreages like what they're doing. Having a strong sense of community is very nice because they can feel comfortable calling up a neighbor if they need a favor.

Farm

The entire farm is 5000 acres, with 3000 acres that can be farmed with machinery. Of those, 2000 acres are in crops and 1000 acres are seeded to perennials. The other 2000 is native pasture with about 100 acres covered by creeks and another 200 acres covered by bush. Put another way, they own 4 sections plus 1 quarter that are all within two miles of home. All of the owned land is adjacent except for 3 quarters which is just on the other side of some land. They also rent 2 sections, one which is 10 miles east and one 5 miles west of home.

The native pasture has never been broken or disturbed that Ryan knows about - it may be that someone tried to till it once. It is wet and low with lots of bush, sloughs, and wetlands, but the biggest issue is the stoniness.

The soil is 90% Newdale clay loam with some coarser pockets and has an agricultural land class around 3 or 4. Salinity affects about 2% of the property and it's an issue that's getting worse everywhere, evidenced by foxtail barley. They are managing it by dewatering with perennial forages. Compaction is also a big issue (about 10% on the surface) especially after wet years. They try to break it up with annual green feed and pasture, especially with the tap rooted species. So far those crops have improved the soil structure but Ryan is careful not to re-compact it. The pH of the soil is high - close to 8 - and they are striving to lower it to a mid-7.

They use mostly well water for both the house and cattle. There are two 70 foot wells, one with poorer quality that isn't used, and four good quality wells that are 20 feet deep or less (one is on rented land). They also fence out their waterways and pump it using solar/wind. The house is on a cistern so they have to haul water if it doesn't rain.

The landscape has some slope and rolling topography that creates low wet and high dry spots, but there isn't any trouble moving across them. There are some creeks that run through the property as well.

Some farmers in the area landscape with a scraper to deal with drainage problems. Ryan would prefer to have the water soak in and they are usually looking for water for the cows, so they try to manage the excess with crop rotation and forage. In July 2014, they had 5-7 inches of rain, and their pastures soaked up enough that they could still drive on them compared to their crop fields which were bogs. In spring 2014 and 2015, their annual grazed fields and pasture both provided ideal seeding conditions (after being chemically terminated) while the cash crop fields were still way too wet to drive on.

Management Approach

There are a number of ideas and ideologies that Ryan has fused into his system. Beginning with a decent rotation, he's experimenting with the pea/canola intercrop (which he sees as peas with canola for moral support). Because of the climate, there isn't enough time to grow it late in the season so he's trying to maximize his results in using that field for the whole year. Holistic Grazing Management is also an influence, especially when it comes to the timing of calving and planning how to integrate annuals and perennials. Extending the grazing season to get the cows to work as much as possible is another. Again, no-till is huge especially for keeping the soil covered and feeding soil microbes.

A big part of the rotation though is the annual green feed polycrop mixtures, which lets him put a cover crop between his cash crops. Gabe Brown in North Dakota and David Brad in Ohio are two of the pioneers in the area. The difference with David Brad is that he gets 22 inches of rain and is able to grow massive cover crops in half of a season after the cash crop. All of these different ideas come together to lower risk by taking advantage of natural synergies and processes, increasing resilience and lowering their exposure to poor weather.

Annual Crops and Forage

Their tame forage is intertwined into their grain rotation. However, their pastures have tended to stay vigorous so they haven't rotated them through the system as much as they might otherwise.

They fit annual forages into the grain rotation as well, either grazing or green feeding cover crops then turning them back into cash crops the next year. Their green feed mix is doing well without fertilizer so far. After grazing a test plot for two years, Ryan found that there was less input but a better return. The annual cover/green feed crops they grow are quite diverse, with the idea that they get the benefit of having a diverse rotation in one year rather than seven. So far Ryan has found that the mixed annuals has compounded the benefits and created a big difference over one year compared to a long rotation.

The general plan of their rotation itself is:

Year 1	Annual Forage
Year 2	Wheat (or canola)
Year 3	Peas (to help break down wheat straw) or Pea/canola intercrop
Year 4	Winter annual (winter wheat or fall rye)

He likes to follow a high residue crop with a legume (like pea) with a larger, more forgiving seed. When they intercrop peas and canola, they seed with a full rate of peas and a half rate of canola then manage for peas. The yield ends up being 75% pea and 25% canola, with past yields around 40 bushels/ac for peas and 10 bu/ac for canola. Finally, Ryan prefers fall rye because it's lower maintenance and more hardy than the wheat.

Figure 1. Photo of a wheat field.

The canola is intercropped with the peas to help them stand up and help prevent disease. Another intercrop Ryan is considering is corn and soybean planted together. He hopes that they won't over-compete with each other and the soybean can help supply nitrogen to increase protein in the corn. The system would also be amenable to grazing.

He's experienced good crops after the annual forages, and has seen rotational research out of North Dakota that shows the benefits of putting corn (in one of the forage mixes below) and peas into rotation. Soybeans would be interesting to try, but they are too risky and complex. Ryan prefers to focus on a simpler rotation (especially with wheat and peas), setting himself up for success with his annual green feed mixes.

Ryan is working on developing some extremely diverse annual forage mixes of both cool and warm season species, which are based on pea/oat and millet/corn respectively. Their seeded forage is relatively diverse as well.

Cool Season Mix	Warm Season Mix	Seeded Forage
Pea (base)	Millet (base)	Alfalfa (tap and creeping root)
Oat (base)	Forage Corn (CanaMaize) (base)	Cicer milkvetch
Triticale	Sorghum Sudan-grass	Meadow brome
Oilseed radish	Soybean	Orchard grass
Grazing turnip	Buckwheat	Creeping red fescue
Hairy vetch	Hairy vetch	Crested wheat
Buckwheat (some)	Sunflowers	Tall fescue
Red clover	Oilseed radish	
Alfalfa	Grazing turnip	
Sweet Clover	Alfalfa	
Millet (some - it doesn't perform that well in this mix)	Sweet clover	
Winter wheat/wheat (leftovers)	Red clover	
Meadow brome/orchard grass	Orchardgrass/Meadow brome	
Ryegrass/Italian ryegrass	Italian Rye	
A bag of sunflower		

The cool season mix is grown as green feed: it gets cut and baled in late July and then regrows to be grazed in mid-September. If he wanted to, Ryan could graze it in July instead. By contrast, the grazing purpose of the warm season mix is to have something standing for direct grazing through the winter (December particularly). He finds that they keep their quality better after frost than the cool mix and also they tend to be tall plants that will grow up through a foot or two of snow. However, they are still working on perfecting the system and are having some problems dealing with keeping down wild oats and volunteer canola.

Figure 2. Cool season mix.

The warm season mix also serves an environmental purpose - increasing diversity, having different types of rooting seasons, as well as having something growing at a different time of the year. Even though the mixes lack perenniality, there is still something growing on those fields, helping the microbial population, and using water all year.

He has seeded pasture mix into former crops, which created an epidemic of foot rot and pinkeye when it was first grazed. He thinks that it was because the micronutrients in the pants were low, and supplemented them with copper for foot rot and iodine for the pinkeye. After a few years now the microbiology has dropped the pH a bit and started to cycle the nutrients more and the cows are doing much better. Ryan thinks part of it is that the alfalfa is bringing some of the nutrients from deeper in the soil. Their forage tests have become much more balanced and closer to CRC recommendations.

Figure 3. Tame Pasture mix.

Cattle

Originally they were planning on downsizing their cows but now they need them to make the system work. The herd is made up of mostly Black Angus but they are in the process of starting a cross-breeding program with potentially Hereford or Simmental for some hybrid vigor. There are 300 cows/300calves/350 yearlings/70 replacement heifers/20 bulls. At the time of the interview the yearlings were being custom grazed. They keep some of their bulls around and developing them for breeding because they've found that bought bulls don't do as well.

They start grazing stockpiled perennial forage in April and then calve on 10 acre pasture paddocks (on a half section) in June starting on May 25th. The make use of the first cool season annual mix regrowth starting in August/September before transitioning to the warm season annual mix until the end of December or start of January. On January 1st they get into the corn grazing program which takes them into April. They keep the calves on grass over winter, weaning them in March after the worst part of the season is over. They aren't able to keep them on the cow yet.

Last year they grazed corn all winter (feeding a couple bales) and moved onto stockpiled grass in April. The corn was strip grazed, with 360 cows consuming 1 acre per day and has now been turned into a decent wheat crop. Ryan applied 70 lbs of N, 30 of P, and 5 of S to the field this year, but could have pulled back. He's put 20 pounds of N on his spring wheat.

The grazed corn consists of one field (about 70 acres) a year which is planted into a low residue crop like pea or canola. They fit it into the rotation where the opportunity arises. In February/March (during the corn grazing phase), they wean the calves which are brought into/near the yard where they get bale grazed in pasture. They then get sent for custom grazing during April and the heifers (depending on market and forage conditions) and steers are sold between August and October.

Figure 4. Views of the top and interior of the corn.

They also graze the riparian areas for a couple days per year. So long as they don't stay too long the grass is healthier and grows better.

They try to move the cows in groups as big as possible, keeping them bunched in order to allow for longer recovery periods. They keep them off the land for a minimum of 60 days but most of the time it's between 90-100 days. The pasture recovery times themselves vary from between 60 to 100-120 days. The paddock size averages 10 acres, which is good for one day with 300 cows.

Figure 5. Cows in pasture.

They don't really have the facilities to keep the cows by the yard. The calves spend a couple weeks weaning there but they have to make sure there's enough bush or stacked hay bales to provide a wind shelter. They have chopped ice in the past because Ryan prefers to not have the cows licking snow in winter if possible. As an alternative there is a heated water bowl at his dad's, and there is an insulated water trough that gets pumped from a dugout or a well. The pasture pipelines come out of the wells and move between sloughs and the 4 dugouts by solar power.

They used to sometimes do some custom grazing (as opposed to sending their yearlings out to be custom grazed). The problem is that grazing rates haven't gone up with cattle prices so it no longer makes economic sense. They did it initially because it was lower risk (particularly because the cows would often get foot rot) and allowed them to practice.

Yields and Importance of Enterprises

Their crops are generally decent although they are still trying to smooth out some of the ups and downs of their production system. Their farm has over 7% organic matter on their cropped fields. They don't know about the pasture, but it appears to be doing as good as ever. Using a single disc seeder on the annual crops has created an observable difference in the soil structure after three years as well. The soil is reacting to changes to the system, but it hasn't happened overnight.

He makes use of the BRIX meter, especially with regard to alfalfa. The BRIX readings in the alfalfa and grass before changing management were at 2 or less and they were having bloat issues (which is expected up to 5 or 6). Now the measurement indicates that the pastures are between 8 and 12, and the alfalfa stems are solid now instead of hollow.

Ryan has noticed that the native grasses they have respond better and quicker to improved grazing management, probably because the underlying biology hasn't been as impacted compared to planted fields.

Figure 6. Native pasture.

Their yields have been creeping upwards over time (e.g. 40 bu/ac wheat was a good crop when Ryan was a kid) which is probably a combination of their system and the weather.

Crop	Yield
Spring Wheat	50-55 bu/ac
Peas	45 bu/ac (75% of that when intercropped)
Canola	40 bu/ac
Winter wheat	55-60 bu/ac
Fall Rye	55 bu/ac

Their green field biomass yields are between 5000 and 5500 lbs/ac. The native and tame pastures produce similarly, with the native pasture improving and performing as well or better with better management. Both types of pasture typically support about 120 animal units on 1 acre for 1 day per year, though a field will typically be grazed 1.5 times per year - once during the green season and once in the dormant spring or fall seasons (on stockpiled grass).

Since changing to a mob grazing strategy from continuous, their native grass production has improved drastically. Though the tame pasture has only slightly increased in productivity, its quality is much better than before.

Normally their distribution of income is 60% coming from crops and 40% from cattle but this year it will be closer to 50/50.

Inputs and Labor

Ryan is in the process of slowly reducing his inputs, but is still applying fertilizer and herbicide. He has more or less stopped adding fungicide and insecticide. Generally, his seed, spray and combine expenses are significantly less than either conventional or organic even though fuel and machinery as still very significant. The reduced inputs compared to organic are because he just doesn't cover his fields as often and has less tillage expense. Conventional farmers spend more by doing a two pass fertilizer harrowing in the fall, cutting the straw lower (which puts more material through the combine), and using more energy with a wider opening when seeding.

Within 5 years, Ryan hopes to stop applying nitrogen completely and have 1/3 of the fields building soil through cover crops. Already where he has a rotation that includes peas and mixed annuals for grazing, he's dropped his fertilizer application by 1/3. Normally they buy hay to help balance their nutrient export but not this past year because of high prices.

The farm has two people working full time, mostly Ryan and his dad. There are usually 3 others doing casual work, including his uncle for 2 days/week in the summer, and Ryan's wife and mom help with processing and moving cattle, giving rides and cooking meals. During the four months in the summer they will work 14-16 hours a day, 6 days a week and the hours for the rest of the year are between 8 and 12 hours/day 5 days a week. The total time required to run the farm is on the order of 7-8000 hours/year. Ryan is able to take maybe two weeks of holiday per year while his dad works a bit less and can be away for 3 months out of the year.

Infrastructure and Equipment

They have ripped out their barbed wire in preference for two wire electric fence which lets them strip graze effectively. For the (extensive) list of equipment refer to Appendix B.

Buildings	Infrastructure
Workshop (40x60)	Free standing corral panels for sorting
Workshop/Machinery shed (40x80)	100s of miles of electric fence
3 loose cattle housing sheds used for winter calving(20x50)	2 miles of temporary polywire
2 houses	60,000 bu of grain bin storage (10% hopper bottom)
Old unused barn	

Risk Management

They do have crop insurance for their spring wheat and canola but don't insure fall rye, pea, or the forage. AgriStability isn't something that is useful for them (or something they qualify for). Even with crop insurance they were spending $15,000/year and would rarely come out ahead. Ryan would prefer to use that money to experiment. The main risk management is being a mixed farm which provides more consistent revenue through having a diversity of crops growing and having the livestock. It's even possible to graze hail damaged crops.

Because cattle prices have been so high for the past two years, they have bought price insurance which guarantees them a high margin.

More broadly, Ryan thinks that insurance skews your management decisions and has served to drive up land prices and simplify rotations so he tries to avoid it if possible.

The complex system gives them a lot of flexibility when it comes to what they grow and where, allowing them to adapt to different conditions. For example, in a wet spring they can seed a green feed/grazing mix or if it's dry they can graze a cash crop (like some fall rye grazed this spring).

Natural

Weeds and Pests

The three big weeds are wild oats, cleavers, and thistles. Ryan is trying to manage them more with cattle but is still relying a lot on chemical, which is necessary to make the zero till work. While their annual green feed has helped a lot, they are still nowhere close to eliminating the issue. Fall rye and winter wheat are both nice because they are competitive enough to choke the weeds out. Wild oat is the main weed problem and herbicide resistance is becoming an issue. Ryan wonders whether he will be able to take them out with the green feed. Ryan doesn't feel the need to fight the foxtail at the edges of fields as the grass takes over and reduces salinity. Dandelions are hard to get rid of in the annual feed but they're a non-issue in pastures.

He has noticed that the weeds do worse where there is less nitrogen in the soil, which is turning into a balancing act between benefiting the crop vs. the weeds.

The green feed is also the main strategy to deal with disease. While he still sprays for fusarium he doesn't usually feel like he needs to. Nevertheless he can't grow peas that often because of an accumulation of fungus in wet spots. There is some sclerotinia but it isn't a major problem.

Insect-wise, he tries to ignore the pests to avoid spraying so that he can keep the beneficial ones around. He hasn't yet had to reseed, but flea beetles are in the canola. They don't bother it as much when it's intercropped with the peas. There have also been some cutworms in the corn.

The main disease problems with the cattle have historically been foot rot and pinkeye. However, as the land has gotten healthier those problems have been greatly reduced and now only 1 or 2 cows out of 300 need treatment. He doesn't use fly or worm control either, trusting that the crop rotation and the long rest periods for the pastures will break the pest cycles. The cows are now pretty healthy in general, except for some of the calves get scours and dehydrate, which might be because the grass is too lush.

An interesting observation that Ryan made was that when he started to rotate cattle through formerly devoted cropland, there was an epidemic of disease like pinkeye but that over time, as the field health has improved so has the health of the cows.

Biodiversity

The wildlife seem to prefer their grazing system to other farms. They have lots of white tailed deer, coyotes, fox, rabbit, beaver, ducks, geese, the odd weasel, skunks, badgers, prairie chickens, lots of birds generally, and maybe some elk/moose occasionally.

Ryan values the landscape and wildlife, hunting a bit of deer and geese. It's nice to be able to sit outside and enjoy a nice green landscape. The bush itself is useful for wildlife habitat as well as grazing and shelter (from the sun and wind) for livestock. Having old bush areas now is quite nice considering so many have been bulldozed. They also collect some saskatoons and firewood (people will come and ask for it). There are two bee keepers that have three sites on their property as well.

They very much value earthworms and soil biology - something there can't be too much of - likewise for smaller insects and pollinators. The mole hills make the pastures rough but will break up the hardpan which then gets smoothed about by the cattle.

Ecosystem Values and Approach

The main ecosystem functions they focus on are nutrient cycling and the water cycle. The motion of the nutrients is meant to activate the soil life and microbes which will in turn help feed the cash crops and pasture. The main idea with water cycling is to get the water into the soil and out through the plants, growing a cash crop in the meantime. Ryan finds it frustrating to see water drain off the surface of the land and would much rather put it to good use.

Seeing the succession from annual to elaborate perennial is also a valued ecosystem characteristic. When the pastures are first seeded there are lots of annual and perennial weeds, but the system overtakes them eventually. The polyculture in both the annual and perennial forages tries to capture multiple canopy layers to intercept more sunlight.

The mob grazing that they do is meant to mimic large bison herds being kept moving by predators. The grazing events and hoof action serve as a beneficial disturbance to plant activity and the soil.

Figure 7. Field post-grazing (left) and looking at the soil quality after peeling back the residue (right).

Environmental Performance

Their environmental performance is quite a bit better than what it used to be: both their perennial pastures and annual green feed have more biodiversity and insects. Their monocultures still have a lot of room for improvement but are still way better than a typical conventional system.

They haven't had any major disasters, but the 5 inches of rain they had at the end of June were mostly soaked up by the perennial pasture. Even the cropland that had recently come out of pasture or the annual mix did much better than other fields. In July 2015, the fields are showing much less drought stress than other farms because of the additional ground cover and the water that soaked in over the last two years. While black soils get to a quicker start in the spring, they tend to dry out later in the season.

Advantages and Challenges

Ryan has a few advantages it might be difficult for someone else to make use of. First is that his youth allows him more energy to figure out and develop a new system that's more environmentally sound. Having an open minded family also helps give him the latitude to try new things. The decent soil on the landscape has responded well to changes in management and had a good baseline fertility, which has probably made the effects of the improvements show up faster than they might otherwise.

Labor is one of Ryan's advantages but is also a drawback. He enjoys working with the cows and moving them every day, which is something that not everyone wants to do. However, he has too many ideas that all require a lot of labor so he may have to start paying someone as their capital increases.

The main challenges are labor and time. Time is the biggest constraint that Ryan faces. He has lots of ideas to accelerate making improvements to the farm but would need three copies of himself to make them all happen. Having a constantly changing and adapting system (which is also a nice feature) makes it hard to train someone to help make it function.

On the other hand, having access to more labor would just speed things up. On the other hand, there are lots of things where there is a lag before a financial or production return. For example a new pasture takes a couple of years to seed, grow, and increase in quality. Another example is their transition from an air shank to a disc drill - it takes three years before it starts working like it should.

One of the big challenges is that there's a real tension between being good at grain AND cattle. His uncle has gotten extremely good at growing wheat and canola, having beautiful crops for 30 years. In spite of his uncle's example, Ryan expects that the wheat and canola system won't be doing that well in 20 years and wants to stay ahead of the curve.

While the community is generally supportive, there aren't any neighbors that are doing even some of the things Ryan is, as they prefer to stick with simple systems that have worked well for 20-30 years. The steep learning curve for the many elements in Ryan's system would definitely have been easier to overcome with some independent research in how to make all of the cool ideas across the globe work in Manitoba.

Motivation and Concerns

Ryan enjoys the work and being outside to watch things grow and respond to the things he tries. Being able to see the benefits of his new management practices gives him motivation to stay on the same path next year. He likes to be free to try new things, which means that he needs to be able to fail. Lowering input costs and reducing debt are both key to having that freedom.

Leaving the farm in a healthy state for his kids or the younger generation to take over would be great. Environmentally, he would prefer to avoid a tragedy of the commons, especially when it comes to digging trenches to move water off the land more quickly. The movement towards drainage rather than soaking the water in and storing it for later use just doesn't seem very sustainable.

While Ryan isn't a huge fan of chemicals, he could never be organic because he hates tillage more than anything. Most zero-till farmers will use a shank machine that still disturbs the ground a bit but Ryan prefers to not be able to even see where he's been.

He has noticed that people have varying degrees of comfortableness with using chemicals: insecticide, fungicide and herbicide in particular. Ryan continues to use them as a crutch even though he likes to try new things. He's motivated by Don Campbell who says not to get carried away - so long as you're moving in the right direction you'll get there.

Ryan tries not to worry too much, but is somewhat concerned that they might not be doing enough or things fall off the rails before he figures it out. He's fairly confident that he'll be able to adjust as they go and has written down his Holistic Management goals and vision which provide a good benchmark to tell if they're moving in the right direction.

He's a little nonplussed by how conventional agriculture pushes the 'feed the 10 billion' message so strongly considering that problem is more a distribution/money issue than production. He's more concerned about ensuring food security close to home.

Learning

Sources

Starting with university influences like Don Flaten and Martin Entz, Ryan has learned a lot from seeing other farmers like Neil Dennis, Ralph Corcoran (the holistic management educator in Moosomin), Gabe Brown, and Jay Fuhrer (of NGPRL). He's also learned from farmers further south like Joel Salatin, Jim Gerrish (a grazing specialist), and Bud Williams (livestock handling and marketing). Dave Pratt's ranching for profit school and Dick Diven talking about calving in sync with nature and saving on feed cost by taking advantage of season production in summer. Ryan also subscribes to the Stockman Grass Farmer.

Most of his information has come from talking to other farmers in grazing circles and holistic management groups. He also keeps on top of what's going on by reading on the internet (even Twitter), visiting lots of conferences and seminars (where he finds that the most valuable interactions are between producers), and following research at the U of M and what's going on in Martin Entz's lab.

Ryan has been influenced by Sally Fallon of the Weston A. Price foundation speaking about the benefits of cholesterol and fat at the Northern Great Plains Conference.

He is also interested in the work of Peter Donovan of the Soil Carbon Coalition doing baseline soil tests to monitor soil change over time. His work involves finding out whether we can offset carbon emissions with grazing and finding out the best holistic and crop management approaches. Gabe Brown is the poster child, whose SOM is now over 10% after starting with 2%. Ryan himself has gone from 4-5% to 7% after starting to turn away from the gamut of chemicals associated with zero-till. Ryan suspects that by focusing on increasing organic matter, everything else should come into place.

Interests

He's interested in Don Huber's assertions about the importance of micronutrient interactions and how Glyphosate can interrupt them. The implications that this would have for health and consumers have been silenced by mainstream agriculture. Ryan has always wanted to talk to U of Manitoba profs like Don Flaten or Martin Entz about this issue.

Ryan is curious to learn more about Jill Clapperton's work in boosting the activity of the soil microbiology and how one might better suit it to specific crops or perennials. He also wants to learn more about the details of finishing cattle on grass and how he might use his existing system to finish effectively. Currently he can do it easily with a 2 or 3 year old but the meat quality is uneven - he wonders where the weak link is.

He would like to learn more about pesticide interactions and how fast you can turn around a field that's been heavily sprayed. He's also curious how detrimental it really is to soil biology, particularly how long it takes it to recover, how we can deal with that, and whether polycropping might speed up the process. So far there has been much more research on the effects on just plants.

Lessons Learned

If he were to go back, he might have started small before scaling up in order to hammer out the details and see if it fits with the farm. Taking over the management of a large farm is stressful enough.

When they switched to the disc drill, they couldn't get on wet fields. Seeding a winter annual on the whole farm dried the fields out early in the season for seeding.

Ryan has found that the key to learning how to mob graze is figuring out how to knock down the grass through trampling while giving them enough to eat and maintaining their performance.

Ideas

What Ryan is mainly interested in pursuing is looking at ways to diversify the cropping system. He would like to do more intercropping but the equipment is the current limiting factor. Relay cropping is another idea along these lines, where he would underseed something into wheat or canola after they establish. He thinks that there is potential to make that system work, and would make better use of the wheat straw with a grass (that would be more lush) later in the season, like annual ryegrass, clovers, or even brassicas.

He is also interested in Permaculture, fruit trees, and Keyline design but for the moment he just doesn't have the time. Right now his focus is on getting more trees on the farm for biodiversity and shelter - probably using the ecobuffer idea. Similarly, compost tea hasn't been a priority, but he's seen evidence that spreading milk gives a huge boost to mineral density and Brix readings. Doing some foliar feeding helped but this is limited by time. Pastured poultry is another idea, but has been slowed because of the labor, inputs required and the quota limitation. Ryan thinks that he could possibly get someone to come in to run this enterprise.

Appendix A - Equipment List

Bush Bull 3pt Mower	JD 444H Wheel Loader
Case IH 1020 Flex Header	JD 4430 2wd Tractor
Case IH 1680 Combine	Keho Aeration Fans 5hp (7)
Case IH 24ft Pull Type Swather	Kelln Solar Mobile Water Troughs (2)
Case IH 5600 40' Chisel Plow	Neco Rotary Grain Screener
Case IH 9250 4WD Tractor	New Idea 4855 Round Baler
Case IH Mx 120 MFWD Tractor	Outback GPS Autosteer
Case IH SPX3310 Sprayer	Polywest Liquid Storage Tank 10000gal
Chevy 2500 Truck 2010	Polywest Liquid Storage Tank 6000gal
Chevy C__ Grain Truck 198_	Post Pounder Pull Behind
Degelman Strawmaster Heavy Harrow 70'	Liquid Storage Tank 6000gal blue
Farm Fan AB 180 Grain Dryer	Ravens 48` Flat Deck Semi Trailer 1998
Farm King 3pt Blade	Redekop Chaff Collector
Flat Deck Trailer	Redekop Chaff Wagon
Grain Guard Aeration 3hp (5)	Redekop Mav Chopper
Grain Guard Bin Heater (4)	Rockomatic Stone Picker
GMC Sierra 1500 Truck 2000	Sakundiak 5000bu Hopper Bins (4)
Herman Harrow 60ft	Sakundiak 8"x40' Auger and Bin Sweep
Honda Foreman 500 2013	Sakundiak 10-2000 Swing Auger
Honda Foreman 500 2012	Timpte Tandem Axle Grain Trailer 2011
IH 9400 Semi Truck 1996	Trail King Stock Trailer
IH 1724 Grain Truck 1981	Valmar Applicator
IH W-4 2wd Tractor	Westeel Hopper (4)
JD 1890-1910 Air Drill 30` 190bu	Westfield 10" PTO Auger

Farm F

Kate and Doug Storey
Poplar Glen Organic Farm
Grandview, MB

Background

Kate and Doug have been farming since 1989 on Doug's family farm, which was bought when he was born. They thought that the farm would be a good place to live and raise kids. They have a strong Do-It-Yourself ethic (and take it to the extreme), and had a strong desire to farm and live in the country. After going away to work in Winnipeg for about 18 years, Doug had always wanted to live there and really likes playing with and driving old tractors. Kate really didn't want to raise kids in the city and wanted to make use of her mechanical, organizational and management skills coupled with her strong work ethic. In a way their farming habit supports the lifestyle in the country they want.

History

Before being settled by Europeans, the area was a summer meeting place between the Ojibway, Cree, and Sioux evidenced by some arrowheads and an axe found on the property. The area offered good fishing but poor wintering so it was not inhabited year round. Later the area was settled by Metis ranchers, who would burn the forest in order to get good spring hunting which left the region very open.

The land was originally broken in 1907 and has been farmed for about 110 years now with Doug's family being one of the first in the area. Both sets of his grandparents and parents farmed in the region. 50 years or so after being farmed, the farm they have now began to decline in productivity. At the time, Doug's parents thought it was related to compaction but Kate and Doug suspect that it had more to do with the depletion of organic matter in the soil.

Until 1993 they farmed the way Doug's father farmed but didn't have much success, observing that the land was becoming very tired. For the next 3 years they tried the conventional approach but didn't like it either, finding that it didn't seem to work very well or necessarily produce a return so they decided to try organic.

After transitioning to organic in 1997 (18 years ago) they still have many questions, experimenting with a lot of trial and error. Figuring out what sells, what grows, and what doesn't grow well in their environment (e.g. flax and barley) have all been issues. Over time they have started to feel that much of the land shouldn't have been cropped in the first place and have been reducing the area that they grow grains over time.

Environment

The farm is located in the cold end of Zone 2 with a short 100 day growing season (although it seems to be closer to 110 now). Local knowledge is that the last frost of the season is around the full moon of May Long Weekend. The reason for the cold climate, despite their relatively low latitude, has to do with the fact that they are at an elevation of 1500 m and their location between Riding and Duck Mountains acts as a valley where cold air tends to settle.

Precipitation-wise they miss the Colorado Low rainfall events characteristic of Southern Manitoba, resulting in about 10 in/yr less than Carman. Most of the rain tends to come during harvest rather than during seeding. However, the climate seems to be getting less predictable over time especially in light of the more recent wet years that have had the potential to drown them out. They have found that there's a balance between getting the crop in too early and having the weeds dominate the fields versus putting it in too late and having the soil be too dry.

Geologically they are on the escarpment of Glacial Lake Agassiz, in a former bay area with a number of washed out gravel ridges. Generally the soil is 2 to 6 inches deep with the soil 300 yards away from their creeks being particularly poor. Vegetation in the area before cultivation was a scrubby woodland, creating a grey wooded soil type generally that varies between great, good and poor soil in the region.

Environmentally, their main concern is that water coming off of others' fields during rains or spring melt is contaminated with pesticides or fertilizer which ends up in the creek and eventually the aquifer.

Neighbors

The neighbors are mostly conventional with maybe two or three organic farmers in the area. As a rule the farms in the municipality are smaller because of the marginal climate and soils. This has led to a trend towards acreages and less interest in farming generally. The biggest farmers in the area are the ones with the best land but most of them still need off farm jobs. The primary crops in the region are wheat and canola with some peas, oats, barley, and beef cattle. Five years ago flax was more common.

The local community looks at the organic farmers with suspicion partly because of the bias against weeds but also there was a cheater who got caught, which has made the other organic farmers cheaters by association.

Markets and Marketing System

Their grain is sold by the truck/B-Train further away to the flour mill in Eli or Yorkton. Their biggest issue is having enough grain to fill a truck, which often takes two years because of their small production volume.

Despite not using the internet to advertise, they do some direct marketing into Winnipeg which is a 4 hour drive away. The lack of a website is offset by maintaining a relationship with their buyers. Kate's mother and sister in law help with the marketing, selling mainly to their friends who are easier to organize. Kate spends a lot of time with the direct marketing, finding that developing the market is quite challenging when making contact and arrangements with the customers but that things run smoothly once a system is in place. There they sell their cows as hamburger as well as their eggs which get a much better price than locally ($4/dozen vs. $2.50). Their nearest abattoir is 1.5 hours away, and they take the animals there and back to the farm before selling them.

Farm Details

The farm itself is 480 acres or 3 quarter sections, with one quarter belonging to Doug's mom (see Appendix A for maps). About 110 of those acres are not actively farmed, mostly being ecoreserve creek area. They are also growing 25 feet of bush buffer where the land adjoins other properties. These and the existing shelterbelts around the property are meant to help keep aerial spray out.

150 of their acres are in crops with three fields which are 40, 45, and 65 acres. Their main marketed output is Cadillac wheat, but they also grow oats for feed and sometimes sell their clover seed. They also grow their own seed for the green manures. In terms their animal outputs, their beef cattle, eggs and weanlings are for sale but they raise a good portion for personal use or to give to family and friends.

The topography of their three quarter sections drops by 35 feet from the West to the East. They have had significant issues with washed out roads and field gullies recently, and strive to keep their ditches grassed to prevent erosion. Further, the fields have a number of sloughs/potholes where rain collects (that can be cultivated when dry) but they don't make a point of draining, partly because there are too many and they prefer to keep the water on the land anyway.

Their main water supply, needed because of the seasonality of the surface water, is the aquifer directly below them, which is strong in iron, manganese, sulfur, and calcium with some salts for good measure. The iron bacteria living in the water create an ugly red sheen on their dishes and sinks. They have a new well which is 17 feet deep, dug by the kids and had only been finished just before the interview. The surface water quality is much better than the aquifer, but relies on the amount of water in the soil and will often dry up with the creek running next to the house later in the summer. Including the one next to the house, there are several creeks on the property that are great rivers in spring, trickles in summer, and dry in fall. Finally, they have a spring on their property (also well mineralized) which runs all winter and they use to water their cows except when the temperature goes below -40°C.

The soil type is representative of the area, being basic and having low natural fertility generally (the topsoil rests on washed gravel) with pockets of good soil. They have noticed that the soil is getting deeper over time but the underlying gravel gets exposed when they plow.

Cropping System

The main crops that they grow are wheat, oats, and green manures. The green manures have traditionally been yellow blossom sweet clover, but they are now experimenting with forage peas and planting a fall rye crop to be tilled in the spring this year. When they first started farming organically their rotation consisted of a plow-down in year one, then wheat, then a feed grain.

Their cropping system now is a ‘two’ year rotation with a green manure in year one, and a grain crop in year two. In practice, their plan is

1) Sweet clover
2) Wheat
3) Pea plow-down
4) Oats

In general they have found that managing livestock is relatively easy but grain farming is difficult to figure out. On their land, they’ve found that phosphorus or phosphate is the nutrient that they struggle with most. To help deal with this, they are planning on moving cow manure near the yard onto the crop fields rather than the hay fields where it normally goes. They have had good success in terms of nitrogen by plowing in sweet clover at the right time of year (to the point of having lodging issues).

Figure 1. Wheat fields early in the season. Kate and Doug are members of the participatory wheat breeding program based at the University of Manitoba and the picture on right shows the variety trial.

Their general approach to cropping revolves around their rotation, which helps avoid a number of pest and disease issues. They have tried intercropping by putting oats with the peas in the green manure rotation, but this didn’t work well because they didn’t mature close enough to work well together. Last year they disked a pea field to plant some of the seeds to see what would happen and have had a fair emergence this year with oats and weeds as well. They have experimented with hairy vetch, but because of the shorter growing season they weren’t able to produce seed with it and the cost of buying seed was too high to justify the lower production they would get compared to further south.

Figure 2. 'Volunteer ' peas with oats and weeds.

Livestock System

Cattle

They currently have 16 breeding cows, 12 calves, 12 yearlings and one bull. Their genetics used to be mainly Shorthorn (and there is still quite a bit in them) but now they are mostly Angus.

Twenty years ago they had a small cream ‘quota’ where one can of cream was picked up a week to be used to make butter in Dauphin. This has created a small issue with the cross-bred cows having dairy genetics and putting more energy into milk than muscle, but this is finally being eliminated. Like their seed, they are play with the genetics of their animals to find something that is well suited to their system and lifestyle and are now quite happy with what they have.

Figure 3. Cattle on small pasture near the yard.

Their livestock system involves a combination of holistic management, rotational grazing, and bale grazing in winter. In the winter, the cows are brought close to the yard (creating the need to move the manure out to the field). They usually turn them out to pasture on June 1, although this year the pasture was too dry – normally they expect the pasture to be a foot tall by June 8. Typically they expect their herd to consume about an acre per day. They keep their yearlings until they are 800 lbs, and then sell them to finish on grain which they aim to do in August.

Electric fence keeps the cows together as a herd, mimicking the effect of predator pressure and gives the grass enough time to recover before they return. Taking care of the grass is important because their roots shrink when eaten, and if overgrazed they no longer have the energy to recover. Knowing the length of time needed for recovery is the biggest grazing challenge because it depends on so many factors including variation in the fields, weather, as well as management decisions like how heavy and how long to graze.

For water, they have 3 main areas: the summer water system which is set up on the north side of the creek, the spring in the south that they use for water in the winter, and an automatic watering system in the corral. They have had cows fall through the ice at the spring in the winter, but this is very rare since the water isn't very deep and they can usually get themselves out.

Figure 4. Spring located at the south of the property. Though not very appealing for human consumption, it was used as an emergency source of water during a bad drought in the early 20th century.

The hay that they grow consists of orchardgrass and alfalfa, and they do their best to use what they produce being in order to avoid exporting those nutrients. Their pasture has some fescue, brome, and timothy (which is essentially gone now – it didn't do that well in the environment) with patches of alfalfa. They have found that when they add manure to a grassed area the alfalfa does very well.

Figure 5. Pasture north of the creek and yard pictured left. On right, the creek which acts as a water source for the north pastures and shallow aquifer.

Holistic Grazing management has been the most influential approach when it comes to managing their cattle. They have experimented with moving the cows at different rates, from once a day (which worked well with a big herd) to once a week. They've found that moving them every 3 or 4 days works best with their lifestyle, balancing the benefits of higher density grazing with being less of a hassle. Overall, they've found that this approach has worked really well with the better root growth producing more grass in those fields and resulting in fewer acres needed per cow.

They are also fans of bale grazing, trying to minimize bale moving by leaving them in the field and allowing the cows to manure right in the field and spread the hay waste. This system doesn't work 100% of the time because of the shape of the farm and the more permanent creeks. Furthermore, they winter the cows on a smaller field closer to the yard, which isn't large enough to supply their needs so they take the bedding pack back out to its field of origin in the spring.

Pigs and Chickens

They have 99 chickens (ISA Browns) for egg production, having sold eggs forever although this might go up since the number of layers that one can raise in Manitoba without a quota has just increased to 300. They use the screenings from their grain crops to feed them once the seed has been cleaned, helping to recycle some of the 'waste' and farm in a more circular way. In the past, they used to butcher their livestock on farm which helped to feed the chickens.

Figure 6. Left: indoor chicken habitat. The chickens also have access to an outdoor pasture area. Right: chicken brooder.

Their pigs are Berkshire, which they are very happy with, and include 1 boar and 1 sow that have 10 little pigs once or twice a year, averaging 16 total. They raise and sell some of the weanlings, usually keeping two for themselves. They had up to 60 hogs in the past but that system didn't last long because a hailstorm wrecked their feed and they were forced to sell them all. They try to time their breeding to match neighbor demand, but educate their consumers to accept a seasonal supply.

Figure 7. Hogs and weanlings. The piglets have access to shelter inside the barn.

Infrastructure and Equipment

For grain storage, they have hopper bottom bins that were sufficient for storage when they were cropping 300 ac (vs. 150 ac today). The hopper bottoms have a dry, bug free environment with a steady temperature that has let them keep wheat for up to 3 years as well as seed wheat that they used for 6 years.

Their infrastructure includes a barn built in 1967 that was built for a small dairy and now houses the chickens and pigs. There is also a metal implement shed, a brooder house for raising chicks, and a shop for machinery maintenance. They have a large amount of electric fence, and the outside of the property is fenced which allows them to graze everything on the property as well as fence out sloughs where they are building up willows for habitat and shelter. They also have a corral, movable wind shelter, and loose housing (a roof open on three sides).

Inputs and Labor

Their goal with their inputs is to buy nothing except for fuel and machinery, as well as salt for their cattle and crushed limestone for their hens. Not long ago, they did a fuel calculation with 3 years of data to compare their consumption with their neighbor and found that their fuel consumption was more or less even per acre.

For labor, they say that it takes the two of them working there part time to run the farm, although they spend a lot of time with do-it-yourself projects in order to save money which is something they enjoy doing. They have had some WWOOFers (World Wide Opportunities on Organic Farms) in the past to help fix fences and move cattle, but that was several years ago. They estimate that they spend 6 hours a day each, averaged over the year with 2 hours/day spent on chores and maybe 10 hours/week spent on pure farming activities. Other jobs include chopping wood, machinery repair, fall canning and killing chickens. The big farm jobs tend to take a small amount of time due to the low acreage with working the ground and seeding usually taking about 5 days.

Yields and Relative Importance of Enterprises

In terms of yields, their usually high-protein Cadillac wheat tends to average between 25 and 30 bu/ac compared to the local average of 36 bu/ac. Oat yields are 50 – 60 bu/ac (with a poor crop being half that) compared to 80 – 100 bu/ac. They haven't kept track of the yields and seed yields of their green manure crops, although they have noticed that they have been improving after the fields lost a lot of phosphate (because of a knowledge gap) although this might have to do with better weather recently. Their hay yield ranges from 1875 to 2500 lbs/ac and they don't keep track of their pasture yields.

The majority of their income comes from beef cattle sales, closely followed by commodity marketing of their grain, averaging out to 1/3 of their total income each. The eggs, pigs and ground beef sales are also significant. They consider the food for personal use as a smaller part of their income.

To supplement their income Doug drives a school bus. Doug is also a good mechanic, having an interest in engines (particularly old grain elevator engines) and likes to find old machinery and get it running again. While this isn't a direct source of income, it helps maintain the equipment on the farm.

While they don't make a large income, their expenses are also very low (including their vehicles) with their biggest expense being fuel. They used to produce almost 80% of their diet between the crops, animals, and garden but now as they are getting older it is probably closer to 50%. This includes all of their meat, about 50% of their vegetables and fruit.

Risk Management

Overall, being prepared and crop timing is their main risk management strategy, having been through droughts and floods in the past. They also find that owning their land is a huge advantage that gives them additional freedom and flexibility. For example, this year they have a terrible looking green manure field where the sweet clover is doing very poorly. In order to deal with this they are considering adding more compost and manure as well as planting peas to improve conditions.

Figure 8. Not a very successful sweet clover crop.

Another strategy is to always keep extra seed on hand in case of a crop failure, particularly because seed is difficult for them to get.

Both their cattle marketing and management strategies have redundancies. While they are normally sold as yearlings in their 2nd fall at 14 months old, they can be sold as calves or in the spring. Otherwise cull cows can be sold for slaughter in Alberta or the local abattoir depending on how they want to spend their time. Their creek areas are available as insurance as well, which they can graze more intensely in drought years (usually once in every five).

They do not have crop insurance, and prefer to keep money in the bank and put themselves in a position where they're able to afford a loss. Crop insurance is more appropriate for people with input costs high enough to ruin them if they lose the crop. They've noticed that crop insurance doesn't work well in the area generally because of greater weather problems, poorer soil, and worse weather. An example of how they've dealt with disaster is that in 2007 their entire crop was destroyed by hail ,they were only just able to recover the seed, were forced to sell all their pigs to avoid feeding them, but were still able to avoid going into debt.

Natural Factors

Kate and Doug are constantly looking for what works on the farm and in different places on the farm, matching what they do with the landscape and especially working with the areas of good soil and gravel. They have a strong belief in leaving space for nature and allowing plants to have their own space.

They also believe in producing and keeping as much vegetation as possible – using trees and holistic grazing produced grass to increase organic matter and carbon storage as well as filtering air and water. The vegetation by the creeks is meant to slow down wind and especially water erosion, doing their part to reduce the siltation of Lake Dauphin. Their 'wasteland' vegetation in the ditches increases their bird diversity which feed on insects in turn.

Pests and Weeds

For weed management in their crops, they like to wait for a good growth of wild oats and mustard (their main weeds) before seeding their wheat. Their technique is to stir up the soil to warm it up for the wild oats to germinate, then cultivate and seed to allow the crop to dominate.

Managing the weed and crop balance involves knowing the optimum wheat/oat window for soil temperature and moisture, as well as the weeds' environmental preferences in order to give their crops the advantage. For them the technique works well because the wild oats germinate early and prefer cold, damp soil. Mustard tends to do better in warm, moist conditions and even though there isn't a cure, it tends to get overtaken by the crops eventually.

Their perennial weeds are dandelions and Canada thistle. While they don't have a control strategy for the dandelion, they cut or graze the thistle back on August 16th just before the weather changes which leaves them unable to survive the winter. They've found that if you wait for them just to start to bloom and let the cows at them, the cows will preferentially go for the flowers.

They don't really have any pest or health issues at all with their livestock. Their grass farming philosophy is that good grass should equate to healthy animals. By contrast, they have had to dial back on some of the freedom of their animals in order to protect them from predators. They have tried to calve in the field but lost the calves to coyotes so they now calve close to the yard where the dogs do a good job of protecting them. Similarly, their chickens used to run wild but foxes took advantage of the hens' limited intelligence so they are now fenced in.

Biodiversity and Wildlife

Being located between the two Parks, they have quite a bit of wildlife, including resident deer, mink, elk, moose, and a cougar sighting. The creek on the property is forested and provides a habitat for beaver in the creek and they used to have a bear that would hibernate next to it. They also have great blue herons that pass through and have a large number of frogs that were quite audible during the tour of the farm.

Direct Benefits

Having extra water is a direct benefit from the uncropped areas – the beaver dam in their creek keeps the water flowing and the aquifer charged through the summer whereas otherwise it dries up in August. The grasses and rushes help to filter the water and the potholes with vegetation hold on to water longer as well which reduces their need to pump.

Figure 9. Beaver dam for season-long water availability.

Some of the other benefits include firewood, mushrooms, cranberries and willow sticks. The mushrooms that they harvest are morels in the spring if it's warm and humid, usually in places with poplar trees where the cows have pastured. They can collect up to 4 large pails of highbush cranberries to make juice and some jelly. They also have some apple and plum trees in the yard but both froze out this year unfortunately.

Beyond the direct benefits, they see the trees as useful for snow catching, shelter from the wind and for the cattle (who can be well protected even in extreme blizzards), and as bird habitat. They've found their pasture (as well as their clover and alfalfa) to be beneficial for bugs and pollination as well, but especially noteworthy has been the return of meadowlarks which had been away for several years.

Challenges

The main challenges for them are that they don't have anyone who wants to take over the farm and is willing to overcome the obstacles associated with it. Another one is that it's very difficult to leave the farm for any amount of time because of the livestock – whether it might be the water system breaking, cows getting out, or fire.

Motivations and Concerns

While they're not really worried about themselves, they are concerned about the fate of the farm and where the world is headed. They see the government urging farmers to take big risks, which is causing problems like canola clubroot, fusarium, and swine/bird flu that they see affecting their neighbors even if they aren't affecting them. The way that society depends on grocery stores that rely in terms on farmers who are on the verge of failure, who in turn are propped up by the oil industry and constant innovation which is becoming more and more expensive, is very worrying. At some point it will get too expensive to continue.

They've witnessed all of the local abattoirs close, mostly because the regulations which were designed for much larger facilities make it difficult or impossible to operate on a small scale. They believe that smaller local places have reduced risk because of the lower line speed and being local makes them much more accountable to their customers. On the grain side, they once sold to a place in Saskatchewan and were worried about getting paid because of some delays and lack of communication. They are a bit concerned that if a mill goes bankrupt they might have to absorb a significant loss.

Ideas not Pursued

Three things that they've thought seriously about but not pursued are their green manures, grazing their alfalfa, and soil testing. The green manure issues have to do with the component plants, particularly hairy vetch and oilseed radish. While they would be nice to grow for their individual attributes and the added diversity, the seed is too expensive to justify the benefits and the climate/poor soil make it too difficult to grow the seed themselves which they've tried on a small 4 ac piece. The main concern with grazing part of their alfalfa hayfield is the bloat risk, which they might still try and offset by grazing some formerly flooded areas to help balance their diet. They don't really have any strong reasons for not soil testing though, apart from not having a good sense of how to do it and will probably do so in the future.

Learning

Their knowledge has come from reading, talking, internet, farm clubs, and experimentation. Probably the biggest source of information though has been from both of Doug's parents who have supplied knowledge like the optimum time to kill thistles (August 16th) and to not keep summer fallow black. They feel that having access to an organic agronomist would be very valuable even if they need to pay for a consultation - having one servicing all of Manitoba is not enough.

Questions

While they are fairly comfortable with their level of biodiversity, their biggest question is how they can continue to improve their soil fertility. They are striving to recreate grassland features by understanding the stages of ecological succession and keeping the ground covered as much as possible. Weeds and green manure are both important for fertility, and the weeds are not so bad so long as they remain in the understory. This year they are experimenting with putting in fall rye after harvest for further ground cover. In general this is meant to build fertility, soil and soil organic matter by keeping soil microbes alive and productive.

A significant question that they have is how to maximize alfalfa health, especially when to cut or graze and particularly when it is late in the season. Knowing how to stagger the grazing in order to balance keeping the grass from getting too old with overstressing it is still part of the learning process.

They would like to know much more about how which green manure species they can grow, what the current state of their soil is, how to best go about spreading manure, how to best manage their cover crops, and finally what the optimum tillage regime would be to help grow their crops.

Lessons Learned

During the 2005 Mad Cow Crisis, direct marketing became much more appealing and they tried a number of things, including meat chickens and selling multi-cuts of meat, gradually paring them down to things that took the least amount of input and energy. They keep their pigs, partly because they have an easy time keeping them and partly since they are very easy to get rid of since nobody in the area has them.

Some of the crops they have given up on are flax, which was difficult to deal with agronomically and had an unreliable market, and barley, which needs a better soil than they have and gives a poor return.

Looking back, they might have built a house from scratch but otherwise they wouldn't change their approach that much, apart from maybe putting less energy into complex direct marketing. Most of what they do has been a natural progression through trial and error although having more information would have made things easier. A couple of common sense things – not leaving equipment close to the flood-prone creek or keeping cows away from pinkeye infected animals – might have saved them some trouble in the past though.

Philosophy and Observations

Kate and Doug have found that there is less risk by being Organic due to the much lower input bills. While there is less volume, they have more control over their crop and the potential premium that it brings. What they are concerned with is getting the most return for the least input, whether that is tractor energy or human labor. Their yields may be less than a conventional yield, but they find that producing those last few bushels comes at a disproportionate cost. They don't agree with the message of feeding the world promoted by the broader agricultural industry when 40% of food produced is wasted and around 30% is going into biofuels. This makes them quite comfortable with their lower yields.

Organic farms are good to have locally even just in order to act as reservoirs of beneficial insects and microorganisms that can eventually recolonize other parts of the landscape. They noticed that the transition to organic production has taken a long time in terms of rebuilding the soil. In the first few years the wheat crop looked miserable, which leads them to think if there is ever a major fertilizer disruption for conventional farmers many of their fields will be extremely unproductive.

In their experience, nobody seems to follow the directions on the pesticide application label, whether it's spraying irresponsibly or being unsafe generally. They've seen a number of people with pesticide burns on their lips turn into cancer over the years, including members of Doug's family. In spite of the spraying, fungus resistance is a huge problem for the neighbors, which has led them towards spraying multiple times a season. The problem is that diseases or pests rebound more quickly than their predators.

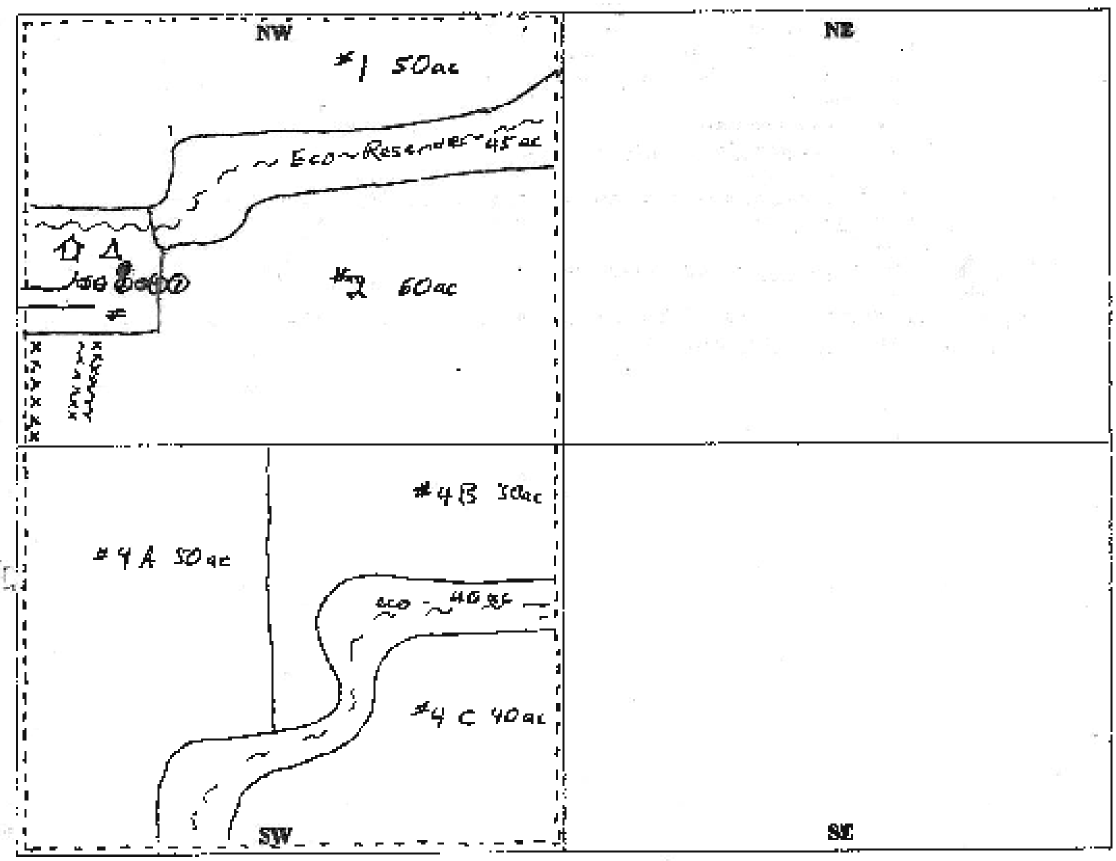
They do not agree with the government encouraging people to go into debt in order to expand their farms. This model forces people to expand their acres every year as they refinance their loans. They suspect that a bumper crop will put a lot of people out of business because the higher harvest and labor costs coupled with resultant low prices will squeeze already tight margins to the breaking point.

Appendix A - Maps

3. **Fields / Plots Map**

Legal Land Description (section / township / range or lot number): 34 24 23 w

Please include only one section of land per map page, and include all fields and plots (OG, TR, CO) included on that section. Please attach / submit additional pages as necessary.



MAP LEGEND

Barns ΔΔΔ
Bins / Storage Units oooo (number, OG or CO)
Buffer Zone ~~~
Bush *****
Grass /////
Manure Storage Areas # # # #
Rock Piles
Shelterbelt xxxx
Stone Walls / Fences ++++
Waterways ~~~

Did you include:

1. Legal land description (section, township, range or lot number)
2. All organic, transitional, and conventional fields
3. Field numbers and acreage
4. Buffer zones
5. Bins, storage units, barns (label with number & certification status)
6. Manure and Compost areas (label with number & certification status)
7. Shelterbelts, bush, grass
8. Yard sites (state if used or unused)
9. Bee Yard sites (draw layout of bee yard on separate sheet)
10. On-farm processing sites (e.g. seed cleaner)

NOTE: If any portions are too congested, please label the area on this map and diagram the layout of the site at a larger scale on a separate sheet of paper (e.g. bin area, bee yard, yard-site, etc.).

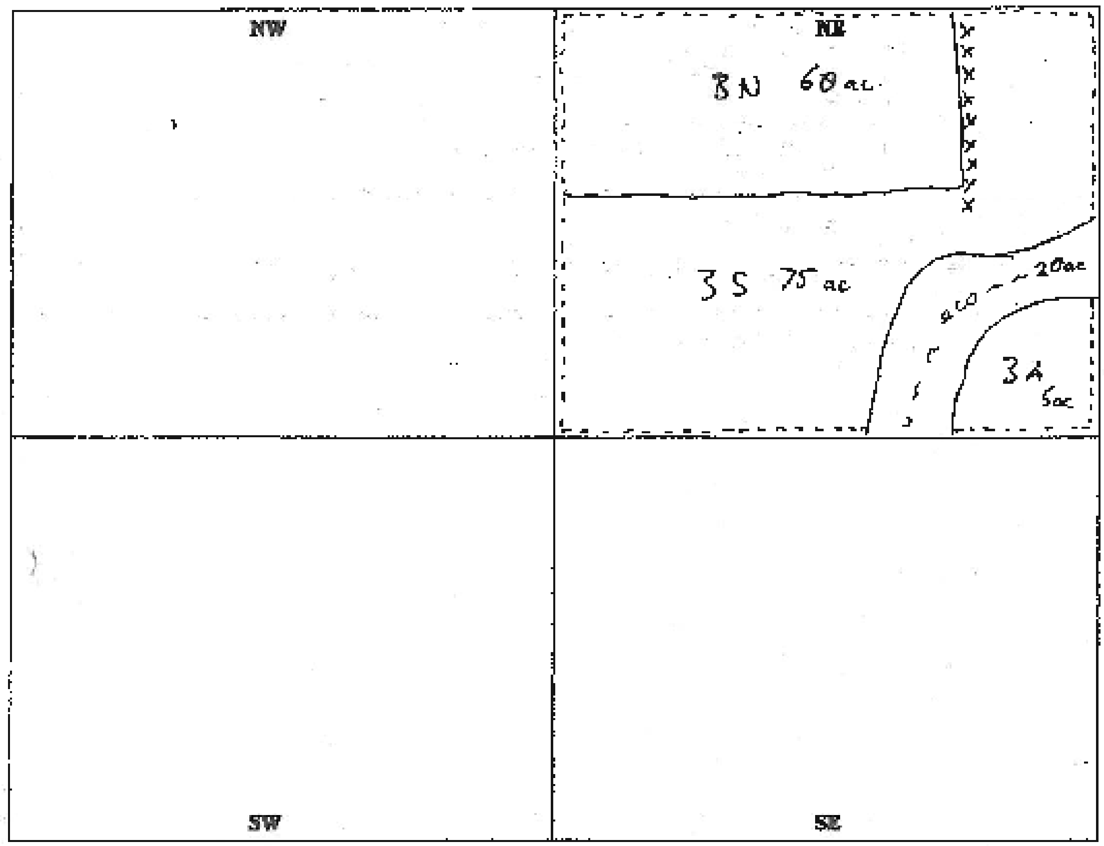
Document: OP/CP-M-P-BC
Revision: 1 (gpw)
Date: 04/01/11

Page 3 of 5

3. **Fields / Plots Map**

Legal Land Description (section / township / range or lot number): 33 24 23 w

Please include only one section of land per map page, and include all fields and plots (OG, TR, CO) included on that section. Please attach / submit additional pages as necessary.



MAP LEGEND

Barns △△△
Bins / Storage Units oooo (number, OG or CO)
Buffer Zone ~~~~
Bush *****
Grass ////
Manure Storage Areas # # # #
Rock Piles oooo
Shelterbelt xxxx
Stone Walls / Fences ++++
Waterways ~ ~ ~

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Farm G

Neil Buchanan
Francis, SK

Background

Neil has now been retired from farming for four years, but he farmed organically for 32 years (53 including his childhood). He has been renting out the land to chemical-using farmers since retiring (they are still very conscientious though). His parents strongly advised him not to farm so he went to school for engineering. However, he soon discovered that he liked farming better which disappointed his dad a bit. At that time he was very young and idealistic and after having a strong religious experience, he wanted to farm the right way without chemicals. However over the course of his career he gradually went from knowing everything at twenty to a bit wiser but knowing less at fifty five, learning 1000 ways not to farm. Since retiring from farming, he has been working for a Seed Hawk subsidiary making no-till drills and he also sometimes gets paid to speak at the occasional event or conference.

History

The farm was first homesteaded in 1906, with Neil's great grandfather homesteading the next quarter over. His grandfather bought the current land in 1929. Neil started working on the farm at 8, being put in charge of the barn, feeding and milking cattle.

Neil purchased his great-grandfather's land, but only had it for four years. His acreage has changed a fair bit over the years: starting with 5 quarters, then selling a half section, later going up to 7 and then 14 but since 1989 he has kept three quarter sections (480 acres). He had the distinct advantage of having his Dad be his banker when he bought the farm, and in 1988 his Dad suggested selling the half section in order to clear the rest of his debt (which he did). It would be nice if every family could pass along land to their descendants.

He used chemicals (only 2-4,D) for the first two years, but questioned what he was doing. He has a natural aversion to chemical farming and couldn't convince himself that it was a good thing. Nevertheless, weeds (the single biggest problem), dryness and the grasshoppers that come with it have cleaned him out many times. There were 10 years where he didn't make any money at all.

When he first started he inherited land left in good shape by his father and had decent crops for several years. After 10 years the weed pressure grew and he realized that farming wasn't as easy as he thought. In order to address it he independently came up with a row cropping system, which unfortunately helped the crops look good but didn't help their yield. Neil thinks that combining fallow and row cropping would have made a positive difference.

Neil's approach didn't change much over his career but he has left a legacy of extensive shelterbelts that were planted a few years in. In 1989 his lentil crop was growing well in the spring until a big wind came up and sheared everything off. Determined to avoid that in the future, he planted 70,000 trees from

PFRA right away and ended up planting around 110,000 trees over a distance of 13.5 miles. A former employee at the PFRA stopped by recently and let Neil know how the planting made the work they did at the PFRA feel a lot more worthwhile.

Environment

The precipitation around Francis, which is the home of the world's largest undeveloped potash reserve, has gone from very dry in the 1980s to very wet for the last 10 years (although it essentially hadn't rained yet at the time of the interview at the end of June). After farming as long as he has, Neil doesn't think that they've ever had an 'average' year. In the 1930s, the south of Saskatchewan was a dustbowl where 4 feet of soil piled up on all of the existing tree rows which can be seen to this day.

The temperature usually dips down to about -40 for 5 or 10 days a year, and the maximum typically is around 35°C although they regularly hit +40 in the 80s. It is very windy just about every day in the area.

Neighbors

There is very little livestock being raised in the area now - it only happens on the most marginal land - which is a huge change from 30 years ago when everybody had some. That said, the neighbor across the road still raises elk and some cows and Neil pointed out that those that hung on to their cattle have been doing well in the past few years. The size of farm has changed significantly in the last 30 years as well, growing from an average of five quarter sections to 3 or 4 thousand acres today.

The farms now are almost all conventional, no-till grain with a few organic farmers scattered around. There is lots of wheat, barley, flax, and canola. Flax and canola are the only money making crops but lately bugs (flea beetles) and diseases are taking their toll on canola. His neighbor occasionally (3 or 4 times a year) sprays close enough that the spray comes into the yard.

Even though they were probably frustrated with his weeds, the neighbors have been pretty tolerant and patient with Neil over the years. Several of them have died from cancer related to direct contact with the sprayer and chemicals. This is true especially of the older generation because they weren't told whether the chemicals were safe back in the 1950s. It is only recently that Monsanto has admitted that Glyphosate is carcinogenic even though they knew 30 years ago and didn't warn their customers.

Markets and Marketing System

Over the years, there has been a stream of organic buyers that come to the surface and Neil has always been able to find marketers. His situation slowly improved from 1987 onward as organic gained ground and there were fewer bad buyers. He still had to sell occasionally into conventional markets until after 1995 when just about everything was sold for a premium. His products typically went to Europe, the US, or BC.

There are certified processors nearby, including Blaine Moore (6 miles away) and Legumex Walker (30 miles away). Neil has still has some cleaning equipment on the farm.

Neil's experience with marketing was either he would track down buyers or they found him. Certain people and organizations would buy certain products, and he would check with them early in the season to see if they were willing to make a commitment. He still gets quite a few phone calls. Really, the bigger problem was the lack of market demand for organic when he started out.

When he started farming organically in 1977, there was no organic market to sell to and no premium to help offset the costs which was the case for 11 years until the late 1980s. His first experience with the organic market wasn’t very positive either. He’s convinced that the grain company downgraded his first (beautiful) organic lentil crop from 23 to 7 cents/bushel, costing him $49,000. In hindsight, the expensive inspection and extensive paperwork needed for organic certification make the idea of direct marketing and farmer’s markets quite appealing.

He’s found that the grain buying system exploits the farmers, who all think they can become rich. Instead, the farmers get as little as possible but still enough that they think they can keep going. Neil pointed out that retail price is a lot less variable than the market.

Support

In the early days Neil was just farming without chemicals without any real support. His Dad was very uncomfortable with it at first, but eventually he more or less came around. Similarly, the community in Francis thought it was weird but now there are more and more people farming organically in the area. Neil's sisters have been mostly positive about it. Neil has always relied (and relies) on his wife, kids, and whoever else came into the picture.

They've gotten a fair bit of support from their certifying agencies (OCIA and later SOCA) which provided connections to likeminded people with two or three meetings per year. Being able to pick other farmers' brains (like Alvin Shuresky) was very helpful. He's observed that of the organic farmers he's met, nobody was ragingly successful or desperately poor, and that organic farming has been more of a life philosophy for people.

Farm (for map see Appendix A)

The farm consists of 400 acres of cropland with 80 acres taken out of production. Most of the uncultivated area is shelterbelt although some is for the yard site. The three quarter sections are stacked on top of one another, and the centre quarter has a big 20 acre slough. Because of the previous wet years (especially the last two) the slough was still full of water in June and quite a few trees had been killed by the high water levels. While the renters are now applying chemical on the farmed areas, the yard and the large slough are still chemical free and provide wildlife habitat.

The main features of the farm include the slough, the sandy 'hill' or knoll on the north quarter, and the 'lake'. Neil built a dam higher up where the water runs into the slough to let him pump water from the slough into a reservoir in order to free some more farmland. This created habitat in that area which is surrounded by trees. Neil plans to sell a 10 acre plot subdivision close to that zone for a couple to build a house while maintaining the organic integrity of the land (the sale depends on the couple selling their own house).

There is a mix of different soil types on the farm. At the edge they have a swath of heavy black loam, there's a small knoll composed of sand, and there are places with black sand. The majority of the soil is a mix of black and brown loam. The subsoil is made up of white, red, and yellow clays.

The quality of water they have on the farm is quite poor. While it's still drinkable (they buy their water), the high salt and mineral content make it fatal for plants. There is a 300 x 60 x 15 (depth) foot dugout a quarter mile away which they use to water the garden (500 gal/day) and a 20 acre slough that has had standing water for the last 5 years. Their property is also at the edge of a very large aquifer with a very high water table.

For drainage, there are two water runs that go through the property. One fills the slough while the other cuts through a corner of the land to fill a slough on his Grandpa's property (although his Grandpa found a way to drain it).

Figure 1. Views of the slough. It's amazing to think that this is not a permanent landscape feature. Trees that were killed by flooding are visible on the right.

Figure 2. Neil on top of the dam he built next to the slough and close to the water run.

Salinity is a concern because there are already alkaline patches on the property. Salt-based fertilizers speed up the process, which is something that Neil is already noticing with his renters. His thought is that the best control is to have lots of trees present to draw down the water table. As a trade-off, after planting so many trees he's found that the willows drop a lot of branches into his crops which he constantly had to pull out. Also, the poplars and maples with their extensive root systems rob nutrients and water from the crop. The many caragana he planted were mainly for N-fixation.

Figure 3. Area between the field and the road that has been affected by excess salt. Salinity is an increasing problem at the edges of fields where left over seed and fertilizer are over-applied.

The topography is quite flat (in keeping with the area) but the sand knoll on north half has an elevation of up to 10 feet.

There is also a small 4 acre horse pasture (two of the acres have never been farmed) where they have two horses. Neil wonders if someone could potentially grow and mill ancient grains there.

Shelterbelts and Ecobuffers

The quarter sections are broken into eight 30 acre fields by 13 miles of shelterbelts. The backbone of the shelterbelts is a group of salt-tolerant, nitrogen fixing species: caragana, buffaloberry, and sea buckthorn. Caragana is Neil's favorite because the others have some issues. As buffaloberry grows its trunk becomes stiff and can be broken by snow. Sea buckthorn on the other hand suckers quite a bit but dies after 10 years. The other species in the shelterbelts are poplars, Scots pine, white spruce, chokecherries, and lots of green ash.

Neil believes that the single best thing anyone can do is to plant a tree. The first of many benefits to shelterbelts is to keep the wind from wrecking the crop, which was his original motivation for putting them there. For Neil they are the most integral part of any environmental system, being important for attracting birds and collecting CO_2. They also catch snow, slow the wind down generally, act as a barrier against disease, provide habitat for insect-eating, birds whose songs may cause plant stoma to open), and help to bring the rain. PFRA has sent people out twice to look at his shelterbelts, including a Contingency from Chile. A student also did a bird study on the property, identifying 60 species that nest in the shelterbelt trees.

Figure 4. Picture of a lane bordered by shelterbelts (left) and a spruce tree that now has the opportunity to grow after being outcompeted by caraganas (right).

Chokecherries are a species that have a lot of benefits. Grasshoppers don't like them but they grow in the habitat they prefer (warm, sandy soil); they have a nice smell when they flower, and their leaves are very pretty in the fall. They also provide food for birds, although the birds are now spreading the seeds all over the farm.

Neil's farm is the site of the original ecobuffer test started by PFRA in 1991, and includes 17 different species and varieties of woody plant. Some of the species are Russian olive, larches/tamarack, dogwood, Manitoba maple, oak trees (bur oak), and American elm.

Figure 5. Views of the mature ecobuffer. It becomes quite beautiful in the fall as the leaves of different species change color in a regular pattern.

Neil has had some pest problems with the shelterbelts and thinks that mixing the species more would have been a better approach. He's noticed that buffaloberries can be supported by other trees which reduces breakage. There have been a lot of spruce shelterbelts planted in Europe that have been decimated by pests.

In order to get them established Neil kept his trees weed free for 4 years to let them establish themselves as strong and healthy. For the first two years, he and his four kids hand weeded all 13 miles of trees, hoeing from 5 am to 9 pm. He used a finely tuned cultivator to get most of them and kept the strips black.

System

Neil's core approach over his career was continuous cropping with a diverse and extended rotation. There were two legumes in a 4 year cycle with lentils being his best cash crop. Peas were the other main legume, but he did experiment with fenugreek and clover as well. He tried growing yellow sweetclover one year for a plow down: it grew to 6-8 feet and was a reasonable success but tied up his field for a year and needed a heavy disc to plow under. His experiments with green manure were more than 15 years ago, when the organic market became stronger and was able to buy all of his crops.

He tried several non-legume crops as well, including buckwheat, kamut, sunflower, millet (for 2-3 years), coriander, oats, and different varieties of wheat (Durum and Selkirk). He gave fall rye a try as well but it gave a lower return because there wasn't a market for it at the time.

Neil's usual rotation:

Year	Crop
1	Lentils
2	Flax
3	Peas
4	Wheat
5	Summer Fallow

The summer fallow would be an adjustment he would adopt now compared to how it was once used every other year. While it's bad for salt accumulation and increased organic matter decomposition, he would include it in the rotation to kill the perennial weeds.

In the spring, Neil would work the ground lightly before seeding very soon after. He would have liked to have a rod weeder in front of the seeder in order to get a good weed kill and also wanted to have precise seed placement and metering in order to avoid double fertilizing and double seeding.

The crops were seeded in rows and cultivated in between the rows. This control system was fairly effective, but Neil understood that he was still treating the symptom rather than the cause. During the season he in-row cropped 3 times, starting with a small shovel, then medium, then large.

After the crop was off, he spread crop residue around after combining. He would often let the flax sit and dry in the field before combining it a second time. In late fall, he would take an implement with narrow spikes and blacken the ground but not over loosening it by plowing at a 5 or 6 inch depth. This helped to keep the tree roots from migrating into the field - the poplars especially.

Yields

His yields were never great - usually around 50% of conventional - and were usually half of what they looked like in the field. The effect of not summer fallowing and tilling the perennial weeds really took its toll. His main cash crop of lentils usually yielded less than 10 bu/ac.

A bit ironically, he had his best crop in 2009 just before he retired. That year he averaged 100 bu/ac of barley with a maximum yield of 150 bu/ac. He attributes the bumper crop to an extremely aggressive tillage regime (14 times!) to kill the large population of perennial weeds (accumulated over 30 years of fighting a losing battle with them) - the decaying root systems supplied nutrients that the renters are still benefitting from.

Inputs and Labor

The labor for the farm took Neil, his wife Pat, and often one other person. Pat took an off-farm job when the kids were around 8 years old, which helped with the family allowance for quite a few years. Overall, Neil's workload has been 10 hours/day year round with long hours for seeding and harvest. This hasn't changed much with his off-farm job because of the two hour commute to Regina. While farming he sometimes took off farm jobs in order to pay the bills. Nevertheless, they've still been able to afford some nice things and aren't saddled with any debts.

Equipment and Infrastructure

Neil is a good mechanic and used a lot of older and invented equipment on the farm. The list of vehicles is pretty extensive, including 11 tractors, 2 semis, 4 passenger vehicles, 2 grain trucks, 2 cultivators, 2 combines, 2 swathers, a home-made seeding machine, a row cultivator system, a big field mower for mulching weeds. When mustard was an issue he would mow their tops off, helping the lentil crop in those areas. However, some of the productive spots often just grew weeds. For buildings he has 10 usable grain bins which hold about 11,000 bushels altogether, a machine shed and shop, neither of which is in great condition. The shop does have a 3 or 4 year old roof though. The shop is an old house that needs a lot of work.

Risk Management

Neil invested in crop insurance occasionally but didn't have it for that many seasons. His biggest risk management strategy was planting the trees: in his experience he's found that the trees actually help reduce drought impact rather than making it worse. For example, in spite of the lack of rain this year, Neil noted that his renter's crops were looking a lot better than the neighbors.

Natural

Weeds and Pests

Neil's main problem when farming was weeds, especially the perennials. Even though he knows they were good for the soil, Quack grass, Canada thistle, and sow thistle were all major and increasing problems. Interestingly, the knoll on the farm was once covered in wild roses which was good for the soil but less good for yield. In order to deal with the weeds he worked the land 14 times to keep it black in order to kill everything in the field. He has a little bit of regret about his stubbornness to modify his belief that crops should grow every year.

Grasshoppers were his number one problem species (although his trees hadn't grown much when they were an issue) but even they aren't generally a problem except in dry years when they take your crop... Neil believes that insecticides are much worse than the alternative because almost all soil organisms and insects do something good.

The only disease problem he had was with barley smut which was a problem simply because he was growing too much barley.

Biodiversity

They have pretty typical wildlife for the most part: coyotes, fox, raccoons, badgers, moles, and 16 stripe gophers. They used to have Richardson's ground squirrel but find that the 16 striped gopher aren't as destructive. Deer are a species they could probably use less of - they've killed a bunch of pine trees and are pests in the garden. Their position fairly close to the Moose Mountains/Hills makes moose an occasional presence on the farm that they see more and more of all the time.

Neil thinks that the single biggest indicator of environmental health is the number and diversity of birds on the farm. After watching the process unfold for 30 years, he guesses that there are 100 species on the farm. Even though the renters are using herbicide and fertilizer, he's noticed that bird numbers and diversity continue to grow. As an example, Neil and his Dad saw a goldfinch and Baltimore oriole fly by 15 years after Neil started farming which his Dad said that he hadn't seen either species since he was a little boy.

Figure 6. A nest with eggs in a hanging flower pot (left) and a mourning dove (right).

He's also found that their deer and moose populations are totally different than when he started. They have 20 deer on their property at any given time and maybe 1/20th of a moose per day, which is a big difference from the bald prairie.

Quite awhile ago, Neil learned about the importance of earthworms but noticed that he didn't have many on the farm. However, he had lots in the yard so he tried moving them out to the field and started seeing them there. From Jill Clapperton he's learned that worms like breaking down flax (which is normally hard to decompose) and that there are native worms that survived the last glaciation by taking refuge in the Cypress Hills. Last year, he followed up on that by going up there and buying some trees and bringing some worms back with them.

Neil also values having bees around. There was a colony of domesticated bees from his neighbor that moved in and swarmed in the shop but the neighbor took them back before Neil could collect honey. Even so, they still have lots of pollinators on the farm.

Benefits

The shelterbelts are now old enough that you could (and probably should) harvest some wood. Neil thinks that it would be possible to heat 5 homes with the excess, and 90% of their heat now comes from the fireplace. The many berries (choke, buffalo, sea buckthorn) offer lots of opportunities for jam, syrup, jelly, and wine. There are also a few raspberries and strawberries around. They have four blackberry bushes on the property that survive well but don't have a long enough season to produce.

Figure 7. They also have a small group of fruit trees in an area outside of the house.

Advantages and Challenges

His strengths as a farmer were having good mechanical and construction skills along with creative problem solving ability. Unfortunately he was less successful at making money but still managed to raise four children while keeping a nice farm.

Making enough money to keep going was the main challenge throughout Neil's farming career, and eventually he just ran out of the energy to keep trying to make it work. In 2010, his last year, the weather was very poor for seeding lentils: the crop went in too late, there was an early frost, and he sold to a company that didn't know how to clean lentils which ended up removing 90% of the crop. In the recent wet years, the biggest challenge was to get the seeding done before the weeds can become dominant.

Motivations and Concerns

Neil is motivated strongly by the idea that he should leave the land working better when he leaves than when he came. We are stewards of the land and that we should be able to farm in the same way for 10 generations without degrading it. He's noticed that a lot of the practices we use now don't do that, and are focused on making money rather than being good stewards (and still making some money). He first started thinking this way back in his first two years when he was still using 2-4,D.

Neil loves helping and meeting people, and would like to be a positive force in the lives of the young people he works with. He feels that he's had a good life with his 4 great kids, and feels that something about his farm that worked a bit better than elsewhere. No matter what he was working on, he always made sure he would see his kids before they left on the bus for school. If he can, Neil would like to stay on the farm and keep it in the family.

Neil is quite concerned about figuring out how keen farmers can go about turning terrible land into a productive farm. Neil has been inspired by the sight of people with lots of passion at the organic farm meetings in Yorkton. However, he thinks that the world is winding down and that the ground will stop producing as much as it does in 10 or 20 years. The big success for canola growers has come with putting on hundreds of pounds of fertilizer, which just isn't sustainable. However, the fact that Roundup makes farming much easier makes it very tough to not use it.

In 2009 he was driving through the Quill Lakes area which is known for its salinity. He noticed that the farmland that was 40 to 50 feet from either side of the road had become so saline that people had quit farming them. These areas are the 'headlands' where people tend to double seed and fertilize in order to finish off any extra left in their equipment. Neil thinks that you can easily put 4 times or 300-400 lbs/ac more fertilizer applied per year than necessary. At this rate, with the naturally high salinity and water table, it's only taken 10 or 20 years to make the land unfarmable.

Learning

Sources

Neil is a believer in the phrase: "When the student is ready the teacher will arrive". Most of his knowledge comes from reading books, talking to people, and finding older farmers with experience and milking them for information (like an old farmer with 60 years of experience who told him about the weed benefit of fallowing). Some of that knowledge, like what he learned about soil science, he wasn't able to put into practice. Rachel Carson's *Silent Spring* was an important influence. The organic community has been a source of knowledge and support as well, and he's attended several conferences to see speakers like Jill Clapperton.

Neil was very impressed with another farmer, Alvin Schuresky. I was unable to find any mention of him on the internet, but he was apparently the grandfather of organics in Saskatchewan. Neil knew him by selling him lentils. He cleaned and bagged his crops, developed his own markets, and planted shelterbelts.

Interests

Neil started out farming believing that a well managed soil should be able to work without any amendments. Since then though, organics has become a lot more open minded about inputs and adding soil amendments is necessary for adding missing nutrients and balancing the soil chemistry. Nevertheless, he believes that a product is necessary to address soil deficiencies, for which there are a lot more options today than there were during his career, especially the products produced by Bio Fert in Langley. He's also interested in using sulfur to lower the pH of the alkaline soils of the southern Prairies, as well as balancing the Magnesium/Calcium ratio. With the benefit of experience, he would now start experimenting with various products on a 5 acre field. In his first 10 years he did try a few products through a church connection, who also taught Neil some soil science and about clay's higher cation exchange capacity. Unfortunately Neil wasn't able to apply that knowledge at the time.

He is also very interested in cover crops - especially tillage radish where the producer grows their own seed. He would also love to know more about the BRIX meter, tillage radish and other cover crops, and products like Biocert. Overall, he would like to see solutions that provide farmers with the ability to have consistent and reasonable success. In his experience there hasn't been nearly enough research and support for this type of agriculture.

If he could go back (or was still in the game), he would do more summer fallowing (i.e. once in five years) and take advantage of some of the new soil amendments on the market. He would try and find a cattle producer to incorporate livestock into the farm system (although he wouldn't manage it himself).

Looking back, he thinks his stubbornness was a big impediment to learning new things. It's important to strike a balance between idealism and wisdom. That said, he wasn't afraid to experiment, trying plow downs, continuous cropping, rotations, and trees. For him to put them into practice though, they had to make sense. For example, after looking into Biodynamics and synchronizing his farm with the phases of the moon, he determined that it wouldn't be useful because the timing of seeding is so critical and there are so few weather windows when it's possible.

Another thing that Neil believes is that people need to question everything. He figures that the main reason people farm the way they do is just because everyone else farms that way. He also thinks that it's better to ask farmers what they need rather than doing research and telling them what to do.

Enterprise Ideas

He's noticed the trend in young people who want to know their farmer and where their food is coming from. He's curious to explore some of the opportunities are out there now but he no longer has the energy to take advantage of them. For example, Neil has been thinking about market gardening and having a greenhouse to grow either an herb garden or cut flowers: garlic and spinach offer a good return for relatively low labor. Starting a bed and breakfast for bird watchers is another idea or just creating a few camping sites. There might also be potential to start milling on-farm and having people come to fill their own bags.

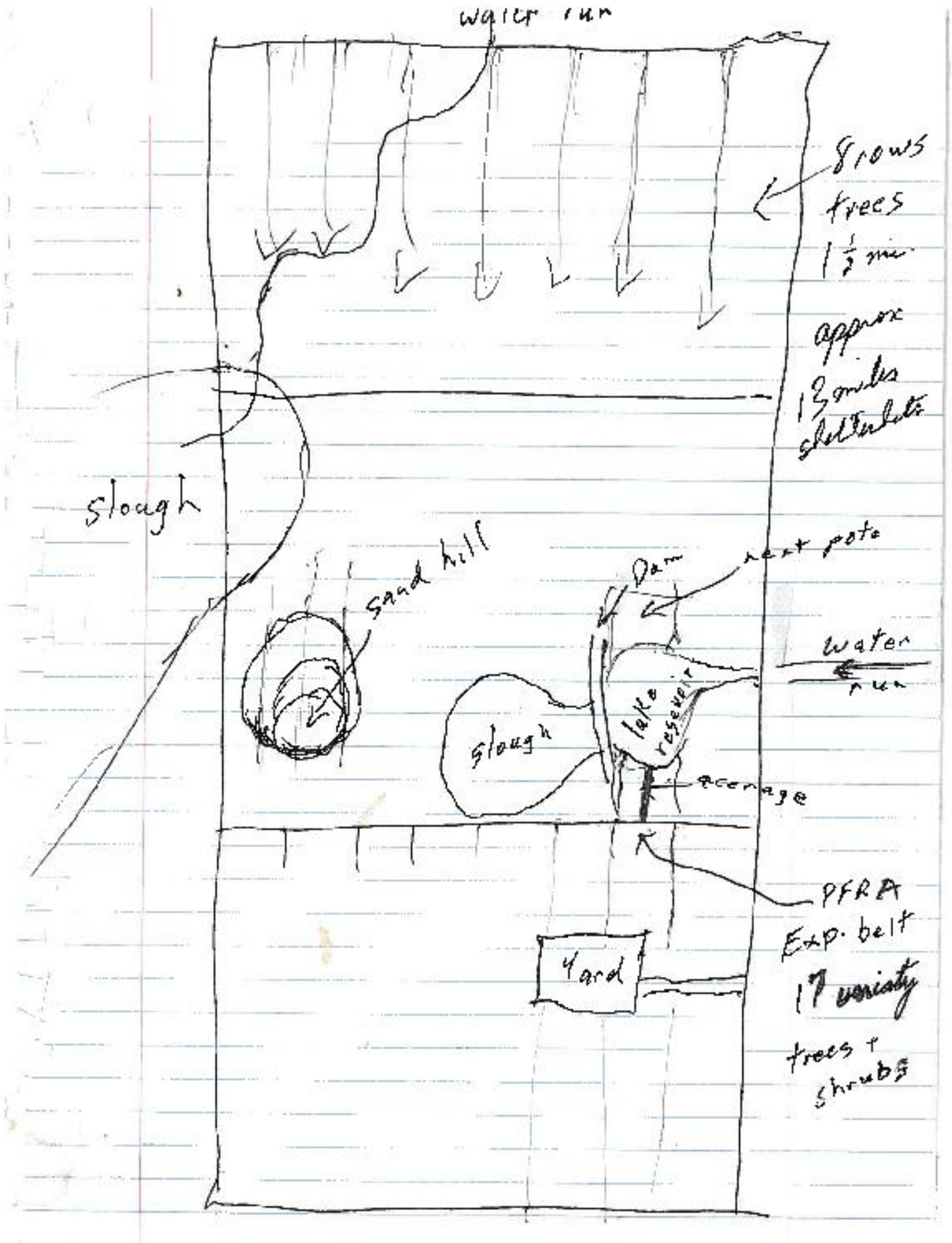
Crops and Livestock Experiment

Neil has recognized the value in crop-livestock integration and rotations that include both. Unfortunately he never had the energy to run both systems. A potential solution would be to have one farmer in charge of the livestock and one to grow the crops.

During the dry year of 1985 his friend didn't have enough pasture for his cattle. To help him out, Neil let him put up a temporary fence on the east side of two of the quarters and let him graze whatever weeds came up. The dugout there was their water source (which dried up by the end of the year). The following year, Neil seeded the entire half section to oats. The grazed area yielded close to double the other half and was the cleanest crop they'd ever had. At the time, wild millet was a bad weed and was not at all present where they had grazed. If he had entered into a partnership with his friend, Neil thinks they would have learned a lot. Having a community of people working together in this way would be really beneficial.

The experiment happened during the worst year of the drought and the grazed areas yielded 30 bu/ac of oats compared to 15 bu/ac in the ungrazed area.

Appendix A - Map



Farm H

Sunrise Farm
Don and Marie Ruzicka
http://www.sunrisefarm.ca/
Killam, Alberta

Background

Don really began farming in 1975 when he got ownership over two quarter sections. At that time he worked part time with his father and brother, otherwise working for a logging company on Vancouver Island. He would get a leave of absence from the company in order to put a crop in and then take it off at the end of the season. In 1983 he began farming full time with interest at 13%, and soon started planting shelterbelts in 1984 being influenced by his logging work.

In his first year he planted just grain but a subsequent crop failure led him to buy some cattle for some diversity. In 1973 he saw that farmers were doing well, buying 4WD trucks and campers which still seemed to be the case in the following years, and he wanted a piece of the industrial agriculture pie. However, year after year their operating loan went up by $5,000 which became increasingly unsustainable. Additionally, he started with a lot of second hand equipment to help avoid debt but it resulted in costly repairs (e.g. the motor went on the tractor in the second year) and their wheat wasn't always good quality. Ultimately their production couldn't keep up with their expenses even with Marie working part-time off farm.

Their change of approach to farming was finally motivated by debt with seemingly no way out. In October 1995, expecting their loan to go up yet again, they wanted to make a change and as it happened there was a Holistic Agriculture meeting that month that promised the possibility of getting off the debt treadmill. During the course, which was two days per month for four months, they learned that the farm is made of small components that have to work in unison to make the farm function well and that they needed to make a partnership with nature and the land.

The goals that they made and wrote down during the course started with the quality of life they wanted: to be healthy, have fulfilled and dignified kids, and to get along with their family. Their secondary goal revolved around biodiversity: noticing that the yarrow and sage problems they had were symptoms of overgrazing, that the meadowlarks had been gone from the farm since 1989, and finally thinking about how to increase biodiversity and increase profits at the same time.

In 1999 he gave his first talk at a Holistic meeting just as they began rotational grazing and keeping cattle out of water by using a solar pump in order to keep it as clean or cleaner than it had been before. At that time Don also started to really prioritize riparian areas which only cover 1.5% of Alberta's land mass but 80% of wildlife lives at least part of their lives in them. This year (2015), for the 50th anniversary of holistic management, the Ruzickas were asked if they would give a tour.

Later on, Don started to attend PFRA meetings where he met ecologists, tree specialists and water specialists while he continued to pursue planting trees. He became involved with a Ducks Unlimited project in 2007 where they developed a Natural Habitat Wildlife Plan, then took pictures and asked what more they could do (which was to build some goose nesting boxes).

History

Before the land was broken, the land used to be entirely prairie without any sloughs or trees - people who know about prairie ecosystems often ask them why they've planted so many trees. In 1907 there were some homesteaders who tried to settle there but they quickly gave up.

Don's grandparents came from North Dakota in 1908, establishing themselves on the land they live on today. When they moved to the area, it cost $10/acre so long as you cleared a certain amount of the land. They ended up buying 11 quarters of land, bringing with them six of the best workhorses they could find and bought all new equipment. There they had 3 sons and 3 daughters, farming with horses into the 1950s, growing oats, wheat and barley to feed to livestock and to sell. The farm was recognized for a Century farm award in 2015. In 1950, two of his uncles took over the farm, keeping the farm very traditional by raising Hereford cattle, continuing to grow wheat, oats and barley, and keeping horses up until his uncle left the farm. Don grew up northeast of the cabin on the farm, and was raised there along with his two brothers and sister.

Environment

The precipitation when they moved onto the land was between 14 and 17 inches in the good years (not including snow). During the worst drought in 2002 there was 7 inches, but there have been a number of 8 and 9 inch years. They figure that climate change deniers are crazy, and have seen a definite change in their rain gauges and pastures over the past years. They don’t think that the changes they’ve seen are totally the responsibility of global climate change though: in the last 3 years there have been 19 quarter sections that have been cleared and their wetlands drained. Though the farmers should be getting approval from the government, they are doing it because those areas produce well for the following 5 or 6 years. Don pointed out that we might criticize people in tropical countries for cutting down the rainforest but we’re worse for pulling down trees than they are.

In terms of rising temperatures, they began raising pastured poultry in 1996 and the extreme heat in July has been killing more and more over time. May of 2015 was the hottest and driest in 113 years. If the weather continues the way it was this spring, they won't be able to survive a two or three year drought.

Their soil is a class 4 solonetzic gumbo, basically a part of the Palliser Triangle that never should have been plowed where bison historically grazed every 3 or 4 years. Though most farmers think that just having something green on the land is good, many of the good quality species just aren’t there anymore because of the management over the last 100 years. The soil where by the cabin is probably class 2, which is why that area is covered with trees.

Environmental Issues

When it comes to environmental problems in the area, Don has been most frustrated by the lack of respect of the oil and gas industry. In 2004 there were seismic testers who came through and asked to do their work on the property. Don was skeptical of their claims that they wouldn't do any harm to the environment since they had never been on it, but allowed them to test on the condition that they promised to never develop the oil and gas and that they didn't drive through a particular part of the farm because it would cause an outbreak of scentless chamomile. Not only did the company put ruts where they said they wouldn't but also sold the survey to a drilling company. In response, Don figured out the cost of dealing with the scentless chamomile and took the company to task. By being so difficult to deal with, he managed to divert the drilling to the neighbors. He really questions the assumption that it's always in the public interest to drill for resources and especially on his land, he's very worried about the effects of how gas well roads open everything up and disturb the environment.

Otherwise, they have noticed that the older poplars are dying and wonder if the prevailing winds from the Edmonton refineries have anything to do with that.

Neighbors

The typical nearby farms are conventional grain farmers who grow peas, canola, wheat, barley, oats, lentils, and flax. Many people still have cattle but those that like shiny equipment are grain only, taking trips down south every winter. Like elsewhere, there aren't a lot of kids who want to farm and the big farmers keep getting bigger. There are very few acreage owners in the area.

There have been some conventional farmers that have come to the Eco Ag meetings (a group that several of the Alberta farmers in this study belong to). These farmers are very concerned with their debt load and say that they have to keep bringing more land into production. Increasing their acreage has been bailing them out for years and ultimately it's a problem they believe their kids will have to deal with. They hope that that so long as they look out for themselves technology will eventually figure out a way for them to keep going.

Markets and Marketing

Don and Marie do direct marketing and get people to come out to the farm as much as possible. They average 200 visitors to the farm a year and never charge people for tours, really wanting people to see what they do. Another marketing approach that they once tried is to visit farmer's markets for three weeks in the winter in order to connect with consumers. Don thinks they could radically increase sales production with videos of their pigs and nature on the farm but being older, they hope that they'll be able to slide their customers into the lap of new farms as they retire.

While they have a website, it hasn't been updated in some time. Their marketing strategy tends to involve responding to emails from people asking about animal welfare and their prices. They will then invite everyone to visit the farm for a tour before they buy. They rely a lot on word of mouth and the

Edmonton Locavoria group (which takes many of their turkeys). If they have extra pork or turkey then they'll take out ads in the Edmonton Journal.

They also turn down a lot of business because they aren't willing to deal with the hassle of selling into Calgary. For example, the Waldorf School in Calgary wanted to source all of their protein from Don and Marie. While they aren't able to supply them, they think that two families working on the farm would be able to supply the demand by dividing the finance, marketing, and labor between them.

They've found that people will start small but often end up becoming loyal customers. They are normally people with health issues, people who want to avoid soy, as well as some professors and students at Augustana University College at Camrose.

Their main markets are Edmonton (40%), Calgary (5%), and scattered around the area (55%). Their dentist and Don's sister live in Edmonton which lets them stack purposes when they make the trip. For Calgary, they visit his brother in Cochrane in October to deliver to 3 families (4 hogs, 60 chickens, 6 turkeys, and a side of beef). There are some high-end restaurants that want their food but they haven't found that it's worth the trouble as the restaurants want the food fresh and not frozen.

For the rest, people really like their pork and it's not something that you can get in the store. Many of their customers are health conscious (often associated with Weston A. Price) who don't like soy in their food or in their food's food. This is a bit of a tough tradeoff because of soy's high protein that fattens chickens up about a week earlier.

They have a good relationship with the meat processing plant in Forestburg for their pork and beef. The company is run by two brothers who find it very hard to keep people there since working in the oil patch is so much more lucrative. This year Don is getting the Hutterites to process their chickens, but they are a little worried because of their low volume, the fact that the birds can't be frozen, and the labeling job the Hutterites do isn't very good even though they are charging a dollar more per bird than they used to. The facility they used to go through in St. Paul is now closed down. In the future Don thinks that a Farmer's Cooperative will be necessary in order to hire a butcher and process all of their meat but it is really difficult to overcome their need for independence.

When it comes to organic certification, they are at the mercy of their processing and sourcing. Though the land is certified, their chickens and turkeys aren't because the Hutterites (who are not certified) are processing them and their pigs are not certified organic because they come from a local farmer who farrows them. However, their eggs and beef are still certified - their consumers are quite understanding.

While they have deep freezers and a walk in freezer they are trying to get their customers to pick their meat up immediately. It used to be more relaxed, but their power bill really cuts into their profits. As it is all of their pork is gone by the end of December and they try to have their beef sold by April.

Social

They get a lot of support from Don's sister, who is a huge supporter and has found them customers. Other relatives are supportive as well but they find the cost to be too high. While Don recognizes this as an issue, he thinks that cheap food is a myth and referenced Joel Salatin's question: How expensive is cancer? They also have a lot of word of mouth support from young people and previous university students.

Farm (for maps see Appendix A)

Don and Marie own 4 quarter sections and rent 1 quarter. Everything is in rotationally grazed pasture with 600 acres of domestic pasture, trees, and wetlands and 200 acres of native prairie with wetlands, trees, and brush. There are 65 acres of planted trees that are fenced off and the wetlands cover 85 acres which aren't grazed unless there's a drought. The yard is about 2 acres with around 1/2 acre for their gardens.

A satellite map of their water from the PFRA shows that they have 85 acres of sloughs and wetlands on the farm. Don has concerns about a practice called pugging in his sloughs and wetlands, which is packing down the soil with cattle so it doesn't drain as quickly. Since fencing these areas out in 2008, he sees them as a backup to his pastures and has grazed them a couple of times during droughts. Though he believes he could graze them more, he wants to build up natural capital for the next generation rather than taking everything for themselves.

Their soil is generally well drained, helped by its high permeability (which mirrors what's on top of the soil). The good litter cover and plant roots promote much better infiltration than is common, with their dugouts filling up much more slowly than the neighbors. Having the land suck up the water quickly allows them to take full advantage of cloudbursts and big downpours. The soil hasn't been tested since 1999 but at that time the pH was 5.9 and the micronutrient concentrations were good. In order to manage fertility, Don suggests using cover crops to pull up different minerals from different zones in the soil.

The farm is pretty flat for the most part. The most distinctive feature is a big hill that favors the west side on one of the quarters. He is planning on working with Takota (a young and passionate farmer, also interviewed for the study) to put in some swales in the near future. The land by the hill is very sandy, which does well if properly taken care of.

For water they have 3 wells for farm use. There is a pump house in the yard (ca. 1940s) which pumps good water and a newer well that was built 30 feet from the old in 1984 that pumps extremely hard water that has to be distilled before drinking. Finally, they have a $13,000 well which, apart from high fluoride and somewhat high sodium, is of good quality. For their livestock they have 10 dugouts (which are all full this year in spite of the drought) that are all fenced. They have tested 6 of the dugouts and their wetland for bacteria, finding 8 coliform colonies per sample in the dugouts compared to 52 in the wetland. The wetland is located on a creek that is exposed to sprays and cows defecating in the water which Don is trying to clean out with cattails. He noted that some towns and villages are now starting to buy wetland land and using it to treat waste.

The components they have added to the farm are the planted tree rows, 240 bird houses, purple marten apartments, sloughs, and the Ruzicka creek/wetland area. They used to plant wheat/barley/oats for bird migrations but found it to be too much of a hassle. There is still value in the practice though since it gives them something to eat and would help bring back upland game.

Figure 1. Trees and shelterbelts are everywhere on the farm. Notably, Don has planted several groups of trees facing the creek and cabin for habitat (pictured right; see map in Appendix A for location and shape).

Only protein goes into the market, with about 2 dozen eggs a week, beef, poultry, and pigs. They've noticed that people are starting to cut back because of the economic downturn. Marie also sells some strawberries and raspberries as a U-pick. They don't sell their garden veggies, their green manure, wheat, and they'll occasionally get rid of a sack of potatoes.

Plants

In the field where the pigs are located, last year Don disked and seeded 7 acres to wheat and this year put a cover crop seed into 4 acres. The 7 acres should be enough to meet the needs of the chickens and pigs, with priority going to the chickens. The cover crop consists of sunflower, hairy vetch, berseem clover, turnips, tillage radish, oats, and barley.

Their tame pasture is 50% alfalfa and a mix of Dahurian rye, Boreal fescue, Cicer Milkvetch, and Fleet Meadow brome. Their new pastures will have up to 16 different species (a pasture for all season), which makes them wonder whether it will give the beef a different flavor. Don noted that a highly diverse native prairie has the potential to put more weight on. By waiting for fall to graze, the pasture reseeds and rejuvenates itself.

Figure 2. Native pasture.

Poultry

For poultry they have 500 Cornish Giant chickens (industrial breed), 50 White Nicholas turkeys and 20 Red Sussex laying hens. They experimented with raising pheasants for 3 years which, despite being very good to eat, were high maintenance and really expensive to raise.

Their turkeys and chickens (both broilers and layers) are raised on green forages which is meant to increase their levels of essential fatty acids. They are kept outdoors but sheltered in order to keep their quality of life high: compared to labels like organic and natural, animal welfare commands the highest price. They are moved once a day, partly in the hope that they can take advantage of the grasshoppers on the property. There are no more than 70 birds in 240 square feet. While the birds only need two, Don gives them 3 feet per bird. For water, Don uses the force of gravity by leaving the water tank in the truck, allowing him to water the chickens with minimal effort.

Figure 3. Chicken and turkey shelters are pulled forward daily by truck. The shelters have a new design because the old ones were too small and heavy. Note the water tank kept in the pickup on right.

Raising the turkeys is very similar to chickens and Don has found that they love being on forage. They've noticed that this production system has caused a huge increase in the omega fatty acids in their eggs. While the poultry don't account for a large portion of their income and are the most susceptible to environmental disaster, they are necessary for selling the beef and pork: new customers will often want to try something small before committing to a side of beef.

Pork

The 42 York, Landrace, and Duroc hogs are also raised on forage in order to increase their omega-3 ratio. In order to maintain their animal welfare, they've had showers for the pigs installed since 2000 and 3 years ago looked into how they could allow the pigs to wallow. They've found that the pigs love to root, especially through bale grazed hay. In order to keep them happy, they're moved twice a day. This spring, they have been eating less grass because there is so little available water but they love it when moisture is good and the grass is approaching 6 feet. Don is considering having them graze on the cover crop in order to consume less grain and to help it break down more quickly. Their great flavor or terroir which is the taste of the land commands a huge premium.

Figure 4. Pigs and pig tractor system.

Beef

The herd consists of 20 cow-calf pairs and 18 yearlings that are mostly Angus but with some Red Poles that can be used for dairy or beef. The Red Poles are flavorful and tender with high butterfat off of nothing but pasture. In order to introduce those genetics they rented a bull from a farmer specializing in grass-fed. They also custom graze 140 or 150 cattle depending on their weight.

Figure 5. Custom grazed cattle on pasture at sunset.

Their cows are rotationally grazed in the summer and bale grazed/extended grazed in the winter. They keep the owned cows closer to home on about 120 acres while the custom graze are kept separate and further out. By rotationally grazing, they are able to deal with spots of low fertility. Within a paddock, by increasing traffic in certain areas using the placement of the water tank/salt/mineral, you can restore productivity to areas that aren't as healthy.

Figure 6. Owned cattle on pasture. Don is able to create paddocks efficiently by stringing a single strand electric wire across the field, building on the previous day's wire and permanent fence.

The calves are born in May and June and not weaned until April. They save the native prairie for late fall and winter grazing, having gone until February 22 and then back out onto pasture in April. In order to bale graze they need snow for water (otherwise they come back to the yard) and conditions that aren't that extreme. They put 10 rows of 3 bales on to an 11 acre area where three bales will be enough for three days at -20. For fields closer to the yard, the cows come home to drink.

Figure 7. Winter bale grazing residue. The rectangular shapes in the foreground are a result of the pig tractor recently passing through.

Further out, they pump water to the cows from the fenced out dugouts to promote water quality and quantity on the farm. The trees they have along the creek also serve this purpose by acting as a sponge to increase the amount of water available in the upland. Allowing trees, vegetation, and cattails to grow around the water forces the spring melt to flow through the biological matter and filter out soil and organic matter.

Don has found that moving cows can be quite easy, although the cows can be frustratingly dense at times. The cows imprint on him so that he can lead them around with the quad, but if there's an obstacle in the way they will just stop even though the path is open.

Because grain is too expensive to grow and the meat is less healthy, they have chosen to finish their cows on grass, which in their case means the native prairie. Don draws his inspiration from Wes Jackson who believes we should be modelling agriculture after the native prairie and its diversity, including legumes, C3, C4, wet and dry tolerant species.

Ecotourism

They rent out their cabin for $100/night to hunters, birdwatchers, and other groups and have gained several customers through the cabin. It still could use running water for a shower and there are some issues with pets and allergies but this is another part of the farm that would be helpful if there were someone to help manage it.

Figure 8. Morning view from the cabin. Though the author is not an expert, there seemed to be a large number and diversity of birds.

Yields and Importance of Enterprises

In 2014, 74 acres (the ecobuffer field) that were seeded 17 years ago yielded 140 1500 pound bales (or about 1.5 tons/acre) with no fertilizer other than cattle. The contractors who were baling it couldn't believe the yield. Otherwise, they don't keep track of the yield on the native prairie and the cattle don't necessarily go into every area.

Compared to their overgrazed pasture in 1989, things have really turned around but even now if they take too much during a drought it can take a couple of years to come back. To keep production high they never cut or bale hay for two years in a row on the same pasture.

In terms of their income, the custom graze accounts for 40% (taking the greatest effort and profit), 30% for the beef cattle, 20% for pigs, and 10% poultry. They also keep and raise a few animals for themselves.

Infrastructure and Equipment

Their buildings include a combined shop/barn where the chicks are brooded, critically important hog and poultry shelters, and the cabin where visitors have seeds of change planted in them. The corral used to be more important but was a lot of work and expense dealing with bedding and spending $2,000 for manure spreading. They have since started calving on pasture in May instead of January (one of the biggest changes they have made), and begun bale grazing with a shelter near a slough in winter where they can come back to the yard if there is no snow for water. The $.10/lb premium they get for grass finished allows them to grow their calves longer and keep them over the winter.

They have probably 30 miles of fence with 24 being single wire electric and a portable solar powered watering system.

The equipment they have includes the quad, the 1974 tractor for moving the hog shelters, the truck that holds the chicken's water, and the truck for pulling chicken shelters. The disc and seeder they've used to seed the wheat and cover crops were borrowed from a neighbor.

Inputs and Labor

Their inputs include salt and mineral (certified organic and animal welfare), all the poultry and hog feed, and every 7 years they hire someone to swath and bale enough hay for the winter. With the 10 inches of rain they had last year, they weren't able to keep up with the growth and had 134 bales (and still have 15 left over). As fuel prices continue to rise, hauling the hay is becoming a huge cost. For fuel, the quad consumes less than a gallon a day, moving and watering the chickens takes a gallon/week, and the hogs take two gallons per week. Don pointed out there is also a fossil fuel price baked into the feed.

Only two people work on the farm: Don and Marie. From April 15 to September 15, the work is 10 hours a day 7 days a week (although it doesn't seem like work!). For winter, the labor is closer to 2 hours a day and includes putting out 30 bales a month for bale grazing and gathering eggs from the chickens. Other activities in the winter include lots of reading (and writing some letters to the newspaper that aren't sent) and doing work in the shop. The shop work (which is more of a hobby) has produced the pig shelters, some infrastructures, and 150 bird houses.

For their success, Don relies mostly on himself and the partnership they have with nature. Marie is fairly quiet but has a lot of wisdom that grounds Don and is something he relies on more and more the older they get.

Natural

Weeds and Pests

While they've built many birdhouses to help, grasshoppers are still the main pest - especially in drought. During the 2002 drought, the turkeys ate a ton of grasshoppers and were the biggest birds Don had ever grown.

Gophers fill a similar niche and this year they had already become an epidemic on the neighboring farm. Don's response is to encourage owls and hawks. However, many of the mature trees they nest in are starting to blow down so he is considering building nesting platforms on power poles. The grass needs to be longer to help the predators catch the gophers so he is planning on letting a quarter go to seed. Because of their strategy of encouraging gopher predators, Don and Marie are concerned by strychnine being approved for gopher control because it will affect all of them, including the badgers, foxes and coyotes.

To control coyote predation of their poultry, they've tried using a radio (which got chewed through) and spraying cologne on the shelters. Keeping the owls out has taken the installation of reinforced stucco wire as a cover for the shelters.

Their pest issues for the cattle are mostly lice in the spring which they've treated with Diatomaceous earth with mixed results (and are considering Neem oil). They haven't had to use Ivomec since 1998 because they don't graze the pasture down too far. Before they had the dugouts fenced for $56/dugout or slough and installed a solar pumping system, there were 5 to 11 cases of foot rot a year with 55 head of cattle. Afterwards, they've had 8 cases out of the 5000 cows and yearlings they've grazed since 1997.

Their 'wasteland' bush is kept down by cattle rubbing on the trees which are killed by the oil they secrete. Don is a little bit concerned about his nitrogen fixing shrubs. His buffalo berries are moving into the pastures as well as the sea buckthorn which aren't native. A solution might be to have a diversity of grazing animals, which would eat different plants at the same time.

Benefits

The direct benefits that they get from the natural areas on the farm include wild Saskatoon berries, wild raspberries, wild strawberries, as well as a lot of mushrooms (although I'm not sure if they eat them). Having nature on the farm is also a part of their quality of life - giving them a significant amount of spiritual value: for them, picking Saskatoons in the bush is like sitting on a beach in Hawaii.

Their berry harvest includes as many wild raspberries, strawberries, and Saskatoons as they can pick, with the option of gooseberries, currants, highbush cranberry (although they're too tart), and red elderberry for wine. A couple of years ago they picked 30 pounds of chokecherries and 9 pounds of sea buckthorn berries (from the 1000 bushes they planted). They've found that buffalo berry, which is a big part of native spirituality, sweetens up after freezing. Their more natural areas act a little bit like a pharmacy, and could even more so with more herbalist and medicinal knowledge. Thomas Berry has added much to the spiritual side of their farming, talking about Haida culture and the sacredness of nature.

The rarer bird species they have on the farm and their experiences with wildlife further that as well. For example, they have seen a mating pair of pileated woodpeckers on the farm who require 100 acres of trees for habitat. In 2004, Don was cutting down dead trees in late October for firewood but on a whim decided to shut the chainsaw off and take a picture. Just after that a woodpecker landed in the tree and made him reconsider what he was doing. Since then they've gotten firewood from their neighbors that are clearing their land. Recently one guy cleared a whole section from whom they now have firewood for 2 years. Altogether they hauled 100 tons with loads weighing up to 3000 lbs. However, Toso their forestry expert thinks that they need to start a woodlot, and by taking strips of trees they wouldn't have to rely on their neighbors.

The ecosystem services that they get include pollination, water sheltering, insect control by birds, using dead trees to supply long term reserves of nutrients, and gopher/mole/mouse control from coyotes and badgers. For pest control particularly they rely on functional redundancy which would be undermined by spraying. Don refers to Rachel Carson's statement that it's impossible to target a single species. For example, when 19 coyotes were trapped one March, the PFRA noticed that there were hawks everywhere on the property that moved in to pick up the slack in the food chain.

Biodiversity

Don believes that habitat is the basis of all biodiversity. Since 1970 we've lost 50% of wildlife even while Bob Costanza (an ecological economist) has estimated that ecosystem services are worth $33 trillion worldwide.

They have 13-lined gophers or black striped gophers which, while often considered a pest, are also an indicator species. Otherwise, they have seen moose, a cougar (2007), and an antelope which was the first spotted in 20 years. They also have plenty of mule and white-tailed deer which will eat with the cows on the same bale during the winter. There are plenty of native pollinators as well, including bees, bats and moths. The diversity on their farm attracts hunters and birders who stay at the cabin.

Don really likes having badgers on the farm because their burrows provide habitat for burrowing owls, foxes, solitary bees, and bumblebees. The pollinating insects are the most important beneficials on the farm. On the tame pasture, having lots of Sprague's pipits, meadowlarks and bluebirds are helpful in keeping their grasshopper populations down.

Don has found that even droughts have benefits. Their wetland did not have cattails before the 2002 drought. His brother needed to pump water to fill his dugouts and got permission from Ducks Unlimited. This gave the cattails the conditions they needed to establish. The same year, their bluebird population exploded with the huge numbers of grasshoppers and by 2009, 97% of their birdhouses were full.

Habitat Creation

Their bird houses are huge for insect control, along with the live and dead trees that provide nesting sites. The ecobuffer on the property is a neat idea for promoting nature and especially pollinator habitat. They find that the birdfeeder outside the house window shows them how they're doing when it comes to their bird populations and diversity.

Ideally, they would encourage pollinators by designing the farm so there is only 150 m between ecobuffer or habitat areas. It's important to make the native pollinators feel welcome on the farm.

Figure 9. Views of the ecobuffer experiment, being conducted in partnership with Ag Canada. Ecobuffers are meant to be a quickly establishing, highly diverse shelterbelt that offers habitat for beneficial insects, wildlife, and beneficial products for humans. This experiment involves different numbers of rows and levels of diversity (see maps for location).

Measured Performance

Since fencing out their riparian areas in 1997, their environmental health has been monitored and evaluated. Gradually they went up from a score of 37% healthy in 1997 to 86% healthy in 2006. Their critical riparian areas needed to be fenced off from livestock to heal themselves – it can take a long time to restore what's been destroyed. The healing does happen though: by resting their pasture they heard the first meadowlark sing again in 2001 after twelve years.

While many ecological farmers are quite happy with the diversity of the species on their farm, Don and Marie have actually had their bird species surveyed. At a species at risk conference in Calgary, an Augustana University ornithologist reported that surveys they had done around Camrose showed that there were less species present than they thought. Don encouraged them to come out to the farm, and in 2004 they documented 41 species. They found 7 or 8 new species every following year up to 93 species in total (this year was the first they didn't document any new species). One of the interesting species that has returned is the Northern Shrike, who takes advantage of the spiny sea buckthorn and buffalo berry plants to impale insects.

Figure 10. The birds are a noticeable presence on the farm, including the robin (pictured left) and goldfinches (pictured right) which congregate outside the dining room window.

Even though their Environmental Farm Plan is way ahead of what's expected, Don thinks that they can still do better by continuing to improve their riparian areas and pasture. Agriculture's weak link is the destruction of habitat and their approach is really trying to maximize space for nature while still producing food. They are really excited about the pollinator work being done by Mark Wonneck and feed off of the passion of Mark and people like him.

Advantages and Challenges

Their water areas are their most protectable advantages. The creek and riparian area is very important for biodiversity (e.g. migrating birds) and as a spiritual resource. The dugouts are a water insurance policy: Don believes they could keep their 25 cows through a 5 year drought without any extra water.

Climate change is a challenge that Don sees coming in the future, including severe winters, droughts, and hot summers. Staying healthy is another challenge that has worked out so far but remains a risk because they're very dependent on the physical labor that he does. Finally, you always have to be marketing when you're selling something at a premium which is a challenge that's very difficult for many farmers to deal with.

Looking towards the future, Don and Marie really want to find someone to replace them sooner than later. The challenge for current farmers is to figure out how to save the abattoirs that are shutting down. Finding a new one can lose you customers if it is not done well and without them they won't be able to sell at all. The best option is probably to put together a farmer's cooperative that could maintain an abattoir, potentially using a federal initiative as leverage.

Motivation and Concerns

One of their main goals is that they always want to have enough food that they grow and raise on their own. They want to redefine that progress really means – working with the land instead of clearing and conquering it.

Don told a story about riding a Palomino horse up to the top of the main hill on the property in 1963 and promising himself he'd own it one day. It took him 20 years before he finally did.

Don is strongly motivated by the loss of dignity that would come with failure. Before starting Holistic management, he was very stressed as a result of the stress of the debt load. After the holistic management they took in 1996 he was able to look at the land and see how they would be responsible for repairing the damage they had done. He feels that they had compromised the integrity of the land and feels that they need to take responsibility for that. 'Putting the train back on the rails' allowed them to pay down their debt and ultimately be hugely gratified by the return of the meadowlark. He firmly believes that "a negative action will give a negative reaction" and that the opposite is also true. There is an inner satisfaction that comes from what they've done that doesn't have a dollar value but fits into their quality of life goals. If two people have a partnership in business and one siphons off the profits, the relationship won't work. This is how Don sees their partnership with nature.

Other motivations include visiting other farms and the stories they hear from the bird, riparian and tree people.

Processing is one of the most pressing concerns they have right now. No matter how good your food is, if the processing is no good you'll have to explain to your customers what's going on. Explaining is important anyways - for example they had to figure out and explain why a few of their pastured chicken breasts were turning green. It's very important in general to look for problems before they show up and get ahead of the game, whether it's in food processing or avoiding foot rot by fencing out the dugouts.

Don has been the chairman of their watershed group since 2001. He has worked with all of the scientific partners and worked hard to plant seeds of knowledge in kids by writing letters of support and thank you letters. 99% of the watershed group membership is farming more than 2000 acres but Don has found that it's the small farmers who are most concerned about watershed health. He worries about who will continue to care once the small farms disappear.

Don doesn't have much faith in the government's willingness to take care of the people. He believes instead that we have to be the people that we've been waiting for. He draws some inspiration from the Hopi in New Mexico who turned down the reservation that was offered to them, settling instead in the most desolate place they could find. Their rationale was that there would be nothing more that could be taken from them so they could be independent.

What Don wishes would happen is that people who want to start farming should talk and get cooperative with others. He thinks that the opportunities are there to make a living (e.g. with market gardens and using farmer's markets) on 80 acres. That said, in order to raise cattle, have a market garden, and someone growing the trees you would need to have 2 or 3 couples working as a cooperative.

Risk Management

Don and Marie are quite risk averse after dealing with the pain of debt load and having to sell two quarters because of the farm debt load in 1995. They do have pasture insurance, having had a 100% pay out in 2002 for $15,000. They never keep more than 25 cows even when the price is good because of the drought risk. Instead do the custom grazing which lets them have much more control over how the land is managed - letting them always have enough pasture for their own and resting land where appropriate.

In order to remain sustainable, staying free of debt is critical. They also need to have multiple backup plans for changes in conditions or the market. For example, processors won't take chickens because of bird flu now (even though it doesn't apply to them) which gives them a strong incentive to look into mobile abattoirs.

A large risk for them is that an injury would be really problematic. Even hiring someone for a short time would be difficult because of the knowledge gap alone. At one point they were close to taking on several WWOOFers like a number of other organic and ecological farmers but simply didn't end up getting involved. They worry about WWOOFers coming out to learn but wanting to work 8 hours a day at a job that isn't 9 to 5. There is also a tension between their wanting to be paid with the benefits of having the farmer's knowledge passed on to them.

Learning

Sources

Don and Marie's journey of learning began with their Holistic Management Course in 1995/96. Since then they have met a lot of riparian, tree, and bird specialists along with the PFRA and Ducks Unlimited. They've gone to a lot of conferences where Don's given around 142 presentations and workshops since 1997. During the winter Don does a lot of reading as well and some of the authors he recommends are Edward Wilson's *Biophilia* (we are all hardwired to care for nature but we need a catalyst), EF Schumacher, Stan Rowe's *Earth Alive*, Wes Jackson and Wendell Berry, and Rachel Carson whose philosophy and values have really motivated them. They also have taken some inspiration from Malcom Gladwell's *Outliers* and the 10,000 hour rule to keep practicing and learning from their mistakes.

Interest

Don would like to learn a lot more about soils and how to keep the soil ecosystem happy. He's very interested in the work of Christine Jones, Gabe Brown, Jill Clapperton, and David Montgomery and gets inspired when listening to Takota talk about the soil. Don is also very interested in using fire as a tool to manage the native prairie. He expects it would help produce lush grasses and lots of flowers but he's not sure he could control it safely.

Takota Coen of Grassroots Farm is working with and inspiring Don to pursue some new ventures. With Takota's encouragement and materials, they are attempting to start some large scale Permaculture. Don would like to raise his hogs more like Takota, by fencing off some pasture close to a slough so that he doesn't need to move the tractor all the time. His existing system takes more time than he enjoys. However, it would be more difficult to manage the pork litters and it would be nice to rotate the pigs through several paddocks. A concern his niece and nephew had is that the pigs will kill the trees.

Some things it would be nice to have would be a 10 gal/min well and a dugout for the hogs. Because of geese and avian flu they wouldn't be able to have a dugout for the chickens but they collected rainwater last year which ended up working very well.

Generally they are trying to find out the scale that they can operate at and to find out if they could take advantage of some economies of scale. Oftentimes, with their chickens for example, this means that they would need another person who would need to scale up further in order to support themselves.

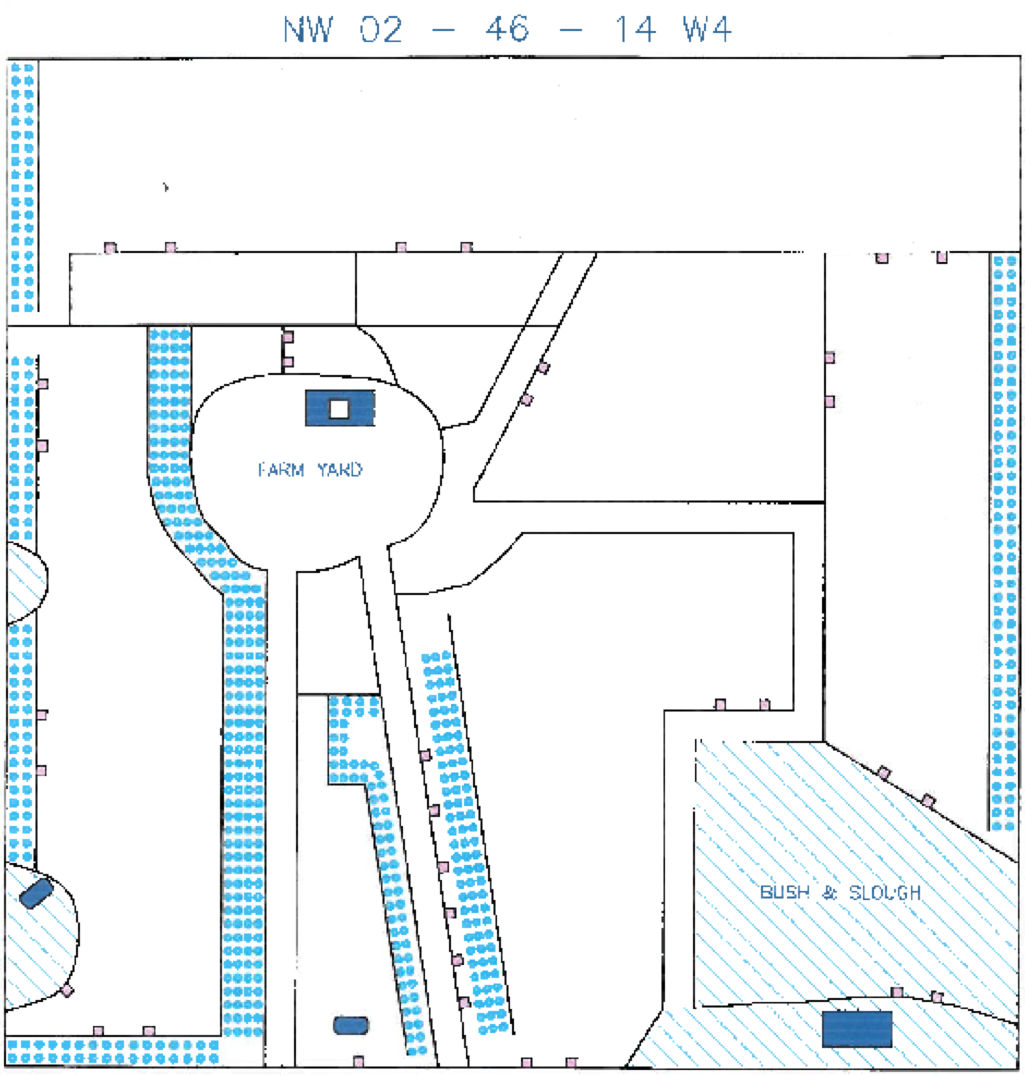
Observations on Ecological Farming

Don made a comment about Mark Shepard, saying that he wants to get rich and tap into global markets but that this is a dangerous game to play. Another ecological farmer, Joel Salatin, tends to treat a lot of the symptoms when it comes to his pest animals - whether it's shooting them or putting on roofs to keep out hawks and owls. While this type of solution can be difficult to avoid, it's important to find the true causes of the problem instead of stopping with a band-aid.

There is a tension between doing well and growing for the poor since they have less ability to pay for organic food. This dilemma is something that hasn't been fully dealt with, and can't be addressed simply by donating something to food banks. However, Don firmly believes that the premium they charge for their products reflects the cost of stewardship.

Appendix A - Maps

Below are the maps of the different quarter sections. The small squares represent birdhouses and the blue circles represent shelterbelt plantings. The shapes to the left of Ruzicka creek are the diverse habitat tree plantings (pictured in Figure 1). Other features of the maps are labeled.



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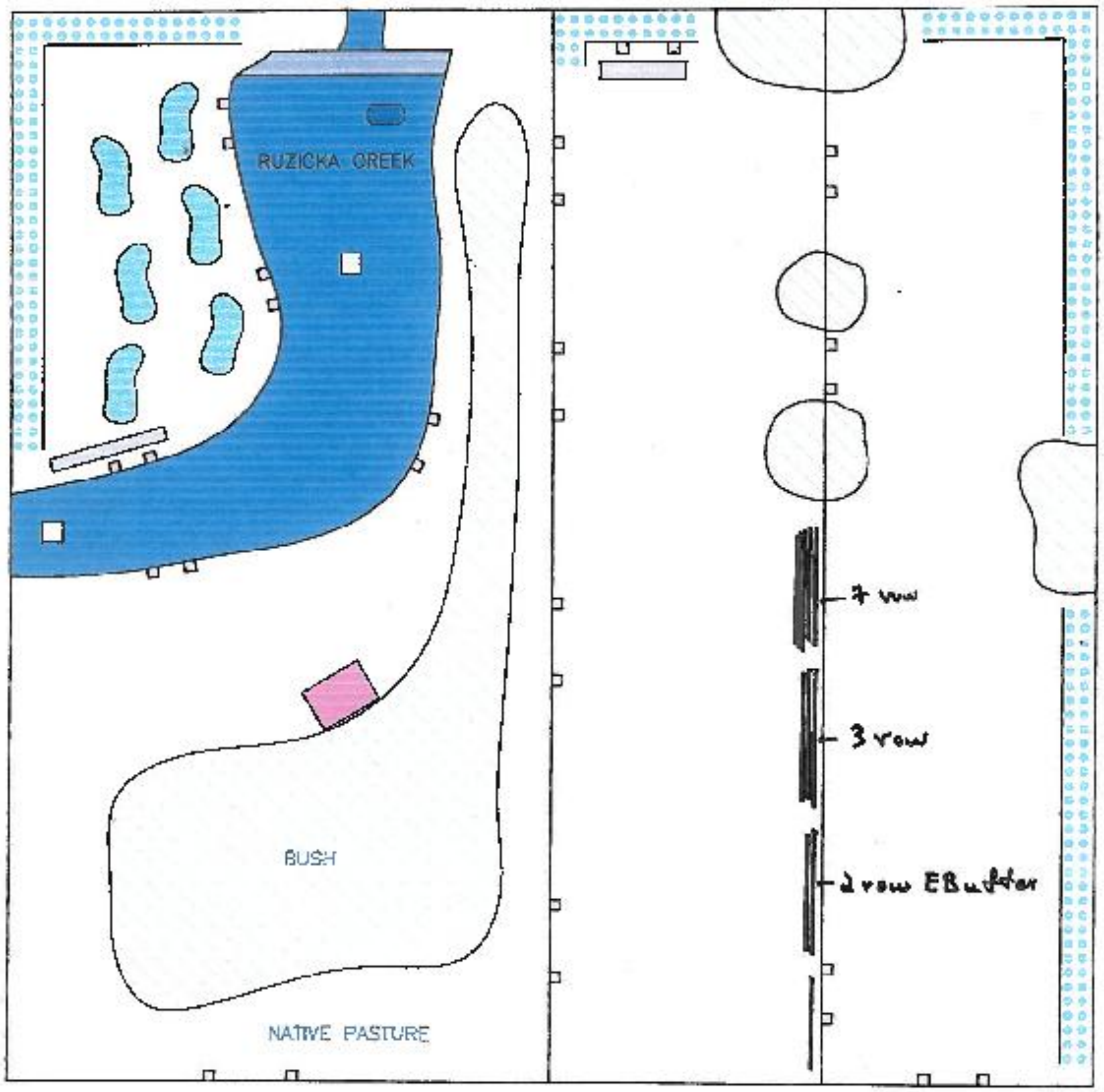

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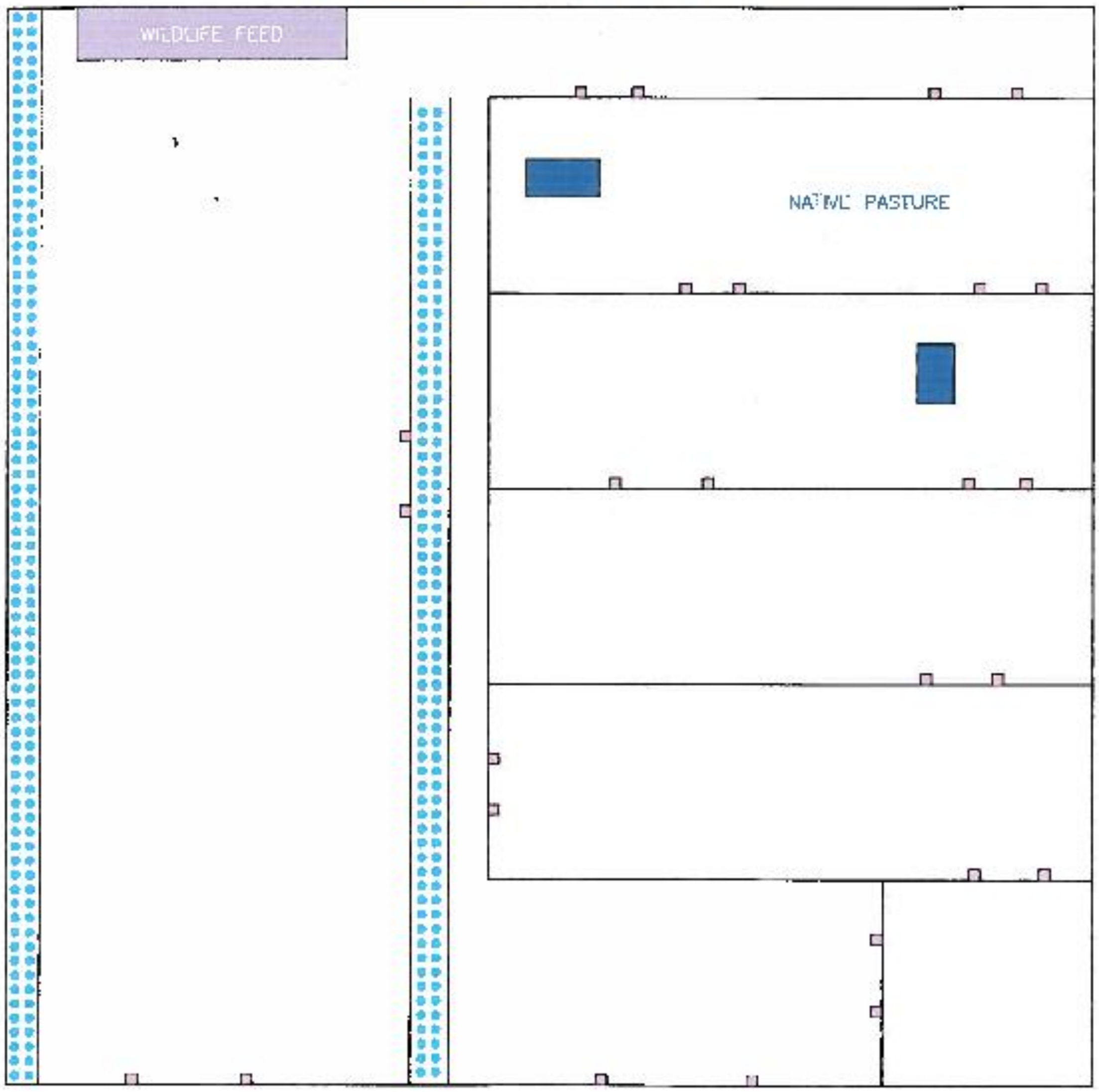

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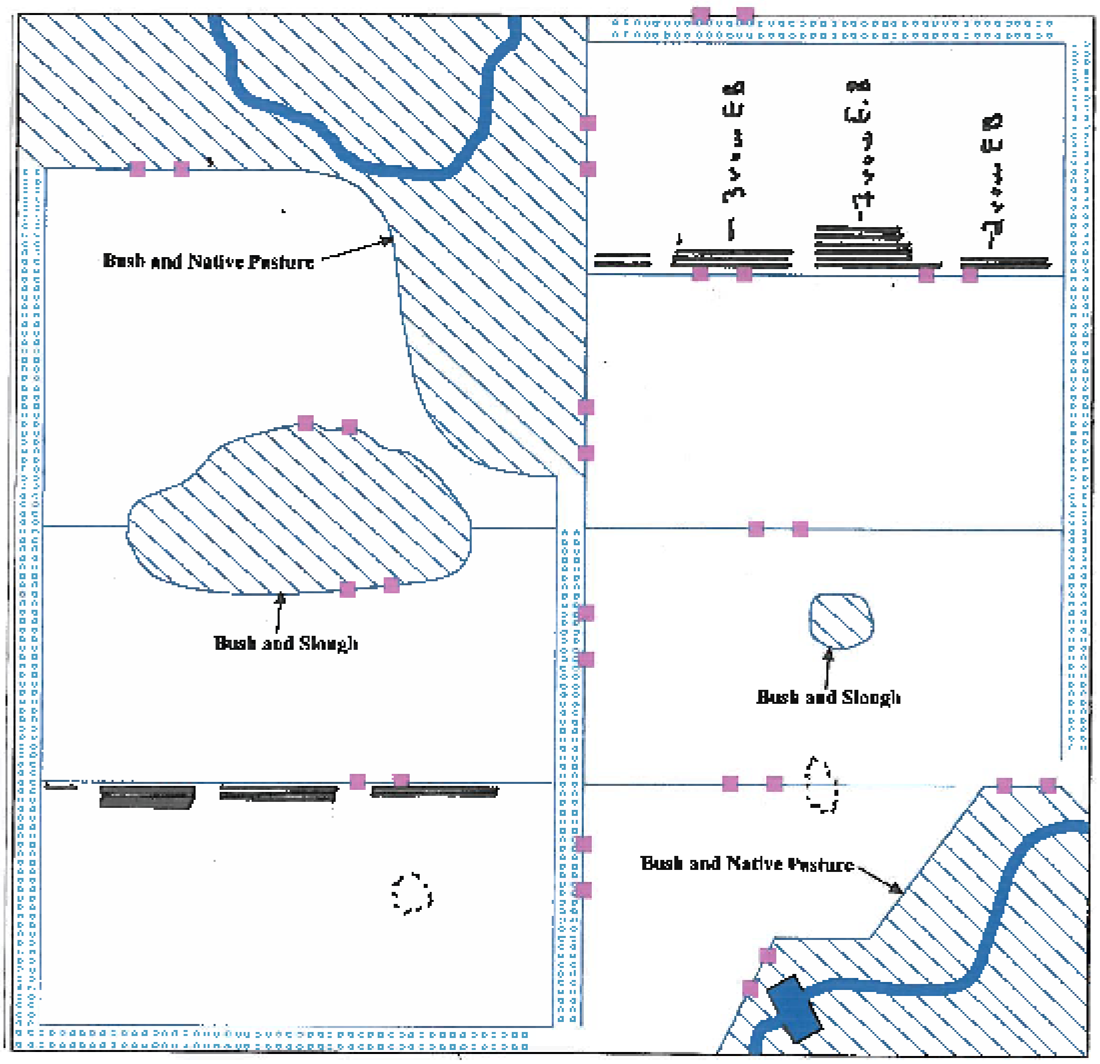

Farm I

Glenn Elliot
Pipestone, Mb

Background

Glenn has been farming for 37 years. He grew up farming with his dad, went through the diploma program at the University of Manitoba, and only worked one day for a non-farm paycheck. Nancy has been farming for 28 years, growing up on a livestock farm, studying animal health at Olds College, then meeting Glenn after coming back to Manitoba to do veterinary work.

Glenn's approach to farming has undergone a 180° shift. After university, he started out as a conventional chemical using grain farmer. The bad grain prices in the 80s led him to focus on mostly pigs and beef in the nineties, as well as exporting hay to dairy farmers in the US.

However, the chemicals he was using made Glenn sick, and he started thinking about transitioning to organic in 1995. He didn't think it would work in Manitoba initially, but he was inspired by Alex Scott in Virden, an early organic leader in Manitoba and founding member of OPAM (Organic Producers Association of Manitoba). Organic agriculture was also attractive because Glenn has always preferred grain to beef, and the premiums allowed him to move back to grain while still maintaining a relatively small land base.

History

Before Europeans arrived, the area was grassland with lots of buffalo and although the farm itself is very flat there is a buffalo jump nearby. Since settlement, 80-90% of the land has been cultivated with only the marshland being left untouched.

The farm has been in the family for 130 years, since 1885. Glenn's grandson is the 7th generation of Elliotts playing with tractors on the land. Glenn bought the farm 32 years ago (1983), buying the most recent quarter section 3 years ago for a total of 10 owned quarters and 4 rented. By comparison, Glenn's brother farms 40 quarters.

Like many of the other farms in the area, their farm is a mixed grain and beef operation. They also raised pigs for the first 20 years. During that time they maintained 30 sows and sold 500 pigs a year, raised from farrow to finish. They left the market because eventually their margins became too tight and they weren't able to compete. Before going organic, they also sold dairy quality hay. The alfalfa helped during their transition period, but they have since stopped in order to keep nutrients (especially phosphorus) on the farm. Their first transition year was in 2000, which was also the year they sold their pigs. Nancy was afraid to stop using vaccines, so they transitioned the grain before the beef.

Environment

Southwest Manitoba is the driest area of the province, but it has been wet for the past several years and is particularly susceptible to flooding from Saskatchewan. Crop yields are lower than anywhere else in Manitoba because they collect fewer heat units (but are the warmest spot in Manitoba?) and are usually drier (unless they get flooded).

The delayed springs in the past couple of years has slowed seeding by a week or 10 days because of cold ground. Normally they can seed sooner than other areas and can grow a wider range of crops.

In spite of recent flooding, wind erosion is more of an issue than water. May is their windiest month, with winds sometimes getting up to 80-100 km/hr. Glenn has noticed that they've been getting more storms in the last 10 years. Plough Winds are high winds that come through occasionally that are about 1 mile wide. Moving at 150 km/hr, they've knocked over 2/3 of the trees in the yard and blew over the barn.

The land is very flat, which is why it is so prone to flooding (and why the creeks can become so wide). The farm site itself is only 10-15 feet above the creek bed. Having such flat land gives the advantage of very little water erosion because it has almost no velocity.

They are located in Prairie Pothole country where the pothole areas have salinity problems. A neighbor tried for 20 years to fix that only to have the last couple of years undo all of his work.

Environmental Issues

The farm is located downwind from an oil battery that separates salt water from the oil before it gets shipped. There are 8 to 10 semi-trailers that come in a day to separate and then send the oil back to Cromer. A south wind makes it very noticeable in Glenn's brother's yard which is a 1/4 mile to the north.

Glenn worries a bit about the flood water, because it is the most likely route for contamination to enter the farm. They test their drinking water, but aren't sure if it affects the crops. They also have spray that drifts over 2 to 3 miles before it settles down. While they don't worry about it that much, their fruit trees look bad when their neighbor sprays during a south wind and they can really smell it.

They did have a Tundra Oil well on the property at one time, and the company was very good to work with.

Neighbors

The typical farm in the area is still mixed grain and cattle, with just a couple of grain farms. The crop rotation is winter wheat and canola if possible, but corn and soybeans are starting to come into the area. Lentils are an option for farmers as well, but they don't compete well with weeds and they have high disease pressure.

Markets and Marketing System

Whether beef or grain, everything is sold as a bulk commodity. The low population density of the area makes it very difficult to do any local direct marketing.

In order to sell their grain they travel between 250 and 400 km. Their main companies are Grain Millers in Yorkton (oats) and Growers International in Wolseley. They also do some direct marketing of sunflowers to Mumm's Sprouting Seeds outside Saskatoon. Glenn also sells some feed grains and markets cattle to two cattle farmers to the east.

Pristine Prairie Organics (PPO) bought some of Glenn's calves in January and resold them to an A&W supplier. He sells his organic cattle at 10-12 months old to a grain-finished organic finisher. The finisher has been selling to 3 different companies: Field Gate Organics (Ontario), Diamond Willow (Alberta), and One Earth Organics. However, One Earth has just bought out Diamond Willow and now controls 85% of the Canadian organic beef market.

PPO is now looking at Spring Creek, which doesn't use antibiotics or hormones but can use conventional feed, making it much cheaper to finish animals. The reason for this is because the recent high price of beef has shrunk the organic premium quite a bit. This year Glenn sold half of his cattle into the conventional market (they are still certified) and was still making money on them: one unfinished steer sold at $2.40/lb.

Glenn spends lots of time on the phone with buyers in order to develop a relationship with them. While the organic grain and oilseed markets are now well established with several buyers, having that good relationship makes it much easier to market.

Glenn and Nancy are certified by OPAM which itself is certified by the SCC, an intermediary of CFIA. As a small side note, two years ago OPAM did their inspection while being observed by 2 people from SCC and 2 more from CFIA. After the tour, most of the officials left, but one of the SCC representatives suggested they test the water.

Farm

Glenn and Nancy's farm is 2200 acres, or 14 quarter sections. 1200 acres are devoted to annual crops, 800 are in pasture and hay land, and there are 200 acres of wetlands. There is very little natural bush: 90% of the trees are located in 3 to 4 miles of 25 year old shelterbelts and old abandoned yard sites. Almost all of the land has permanent fence around it. 1280 of the acres are in one block (and include the rented land), which helps them be less concerned about maintaining buffers. The quarter located 10 miles away is protected by two tree rows.

Half the farm consists of a large block of sandy soil perched on top of a clay subsoil. On 20% of the land to the northwest, the clay loam comes all the way to the surface but the other 30% of the farm is all sand. Only one field has any stoniness. The soil pH is relatively high, ranging from 7.7 to 8.2. While some of the land is class 3 most is class 4 or 5 which helps to explain why many farms in the area still have livestock. The land is relatively good at growing legumes. Most of the saline/potholed areas on the land are to the West, around the creek.

The well servicing the yard is 1 km away, dug into 16 feet of sand before the clay since they aren't able to have a well in the yard because the clay is so tight.

There is a lot of water that passes through the farm between Stony Creek and another creek on the farm. Stony Creek, which was less than 200 feet wide during the interview, can get to be a mile wide before it drains into a large marsh area. While it used to dry up by early or mid-June (and sometimes didn't run at all), Stony Creek has been constantly wet for the last 5 years. In dry years it's possible to grain crop right through the other creek. In July 2014, it rained 15 inches in 5 days upstream which caused the creek to rise 1.5 feet in 24 hours and covered between 5 and 10 thousand acres of land.

The quarter section closer to the marshy land may be the worst land to work with. The water table is very high and the ground is sometimes like quicksand. In drier times this isn't a major issue.

Currently, 60% of the land is in annual production and 40% is perennial. Though Glenn prefers growing crops, annuals will never get to 100% because at least 10% isn't suitable for grain production due to being either too wet or low. In the future he may start selling forage again although the value of crop-livestock integration is being discussed at organic meetings. Another option may be to start custom grazing for local graziers, especially in the annual cover crops.

Some of the buzzwords that apply to the farm include intercropping (mustard and peas), 3 year+ rotation with forage, and conservation agriculture. He is growing forage peas and oats for a plow-down green manure this year. He also brings his livestock in for summer grazing of the cover crops and swath grazes them in winter. As a general rule Glenn tries to have as much stuff growing as possible.

Rotation and Grain

The annual field rotation involves one year of soil building, followed by wheat, then an undetermined crop, then another year of soil building. There are generally different crops on each one of the different fields based on where they are in the rotation some broken up by tree rows. The crops they grow for sale include wheat, flax, oats, sunflower, field pea, and mustard. Last year they intercropped field pea, mustard, and barley but took out barley this year because cleaning was difficult and the benefit was small. They no longer grow canola. They tried growing organic hemp once but the combining challenges coupled with the fact that the company went bankrupt before they got paid made it an unhappy experience. Lentils are something they consider as well because it's in demand in the organic market, but weeds and disease make it risky.

Even before transitioning they had a long term rotation that included alfalfa for 4 or 5 years. They then followed with 4 or 5 years of grain rotation, and noticed that the needed less inputs in the first couple of years.

In more detail, the wheat fields are cultivated and harrowed once before seeding. Glenn doesn't do any more cultivating if there is low weed pressure but he weeds using a rod two days after seeding. The Rod

Weeder is a round rod that runs backwards and flips weeds up onto the surface. It only takes half the power requirements of a cultivator but only works if it is a hot, dry sunny day. Glenn also uses it for thistle control in his cover crops.

Some fields in the third year of rotation need two cultivation passes in order to deal with heavier weed pressure. The recent wet years have made this more difficult. After the crop is off, he cultivates twice. In order to take land out of perennial forage he till aggressively, using a moldboard plough.

Cover Crops

Glenn seeds cover crops in the last week of June up until July 1st. There are usually clover, oats, peas (N-fixing), radish (to break up the soil structure), and sunflower (deeper roots). The purpose of the cover crops is to help build soil organic matter and fix nitrogen and Glenn doesn't think that legumes alone would produce as much organic matter.

Glenn and Nancy are one of the few farms doing winter swath grazing of cover crops where he will add buckwheat, millet, and turnip to the cover crop mix. He will normally swath in the first week of September to avoid the frost (September 11th last year), which can be problematic because millet and oats draw up poisonous levels of NO_3 for cattle when they freeze. He then grazes the swaths starting in December (November 22 last year). Glenn grazes the swaths until January 20th, giving them a small portion at a time. The cows do some bale grazing later in the winter, feeding in spots that need extra nutrients or are struggling with salinity.

The swath grazed fields, which are swathed 60 days after seeding, aren't plowed until the next spring. Similarly, the plow down peas are disked in just as they are flowering at 60 days or the summer grazed areas are grazed at around the same time. He is currently growing some clover for plow down (which is mostly weeds now), which allows him to hit the weeds at a different time than normal. This helps the crops compete better with the annual weeds (but doesn't do well against the thistles).

In general, time management is very important regardless of the crop because you need to know when the weeds have to be tilled. However, excessive moisture like the rain in the previous year sometimes makes it impossible to get onto the field.

Pasture

Their grazing land has been in pasture for some time now (almost 10 years), and Glenn is gradually rotating the land back into annual crop land, shifting the balance to more grain and less forage. While he grows all of the hay on the farm (and definitely doesn't sell it anymore!), he is gradually phasing out forage production.

Their pastures have become a mix of alfalfa, meadow brome, cicer milkvetch, and tall fescue, which get either grazed or baled. The tall fescue tends to thrive in areas where the brome doesn't do as well. Glenn has found that the plants are better able to stay diverse under organic practices, probably because alfalfa has less chance to take up as much phosphorus and dominate. They have tried timothy, but it tends to prefer wetter land and grows well with reed canary grass closer to the creeks. After several years, rotational grazing seems to help the alfalfa survive but the milkvetch is gradually taking over, to the point of becoming weedy. It might be more of a concern but the cows really like it.

The forages are established by under-seeding them with oats, allowing them to harvest the oats. If it's a dry year, the oats are cut sooner to help the perennials establish. Both annuals and forages are seeded with an air seeder with 8 inch spacing. Glenn would like to have a bit more spread to better compete with the weeds. A Valmar could be used to broadcast seed and then follow with a harrow.

Last year after freezing he baled cattails and rushes for use as bedding. Knowing that cattails draw up phosphorus, he suspects that he can use to bring more fertility into the cropped areas. He's seen a noticeable difference on the wheat field that he seeded this spring so far.

Livestock

They have 78 Charolais-Red Angus beef cows, 79 calves, 4 bulls, and 20 yearling heifers bred for replacement. The Charolais finish more nicely and take the right amount of time to get to a good slaughter weight while Red Angus do better on forage diets. The cows get almost no grain in their diet. The calves are weaned at 7 months, fed for another 3 with 10% grain in their diet, and sold at 10-12 months.

Figure 1. Looking up a steep berm at some of the cows. During the Dirty Thirties, there was a huge amount of soil that built up around the fence lines, creating berms like this.

This past year the livestock were kept close to the yard and they used heated water bowls. Glenn relies on licking snow when the cows are further out and brings them home if it doesn't work - he isn't keen on chopping dugouts. During the summer they have a number of dugouts, sometimes pumping water (the dugouts aren't fenced), and have shallow buried pipelines to bring water to some of the pastures. Glenn also has 80 acres on a quarter section mostly covered by Hunter's lake. The Habitat Heritage Corporation has made an agreement with them to fence out the creek area and keep the cows away until the fall.

Figure 2. A dugout near the yard.

During the summer the cows are moved every 7 to 10 days, normally on 70 acre pastures. They're moved every 4 days when swath grazing in the winter. Because they only eat 80% of the swath, the vegetative material left over breaks down more slowly to release more nutrients in later years. Glenn splits them into 4 groups until breeding season is over then mixes them together again. Glenn spreads manure from the feed areas onto the cover crops before seeding and then grazing in September. He is thinking about disking in the more saline areas to enhance the cover crop benefit.

Yields and Importance of Enterprises

Their wheat yields, always coming after a plow-down year, average 90% of what's normal for the area (quite a bit lower than the Manitoba average of 52 bu/ac). Their oats normally yield 50 bu/ac, but last year and the year before were 100 bu and 70 bu, respectively.

Crop	Average Yield
Wheat	30 bu/ac
Oats	50 bu/ac
Flax	11 bu/ac
Peas + Mustard	30 bu/ac
Sunflower	20 bu/ac
Barley	40 bu/ac

Their hay yields on one of the baled fields are around 1600 lbs/ac and 2500 lbs/ac (closer to average) on another. Their pastures are more difficult to quantify, partly because 1/3 of the biomass gets left on the field. Glenn keeps track of how much gets grazed in the winter: 60 acres fed ninety 1400 pound cows for 60 days (i.e. 1 acre of swath grazed per day). Glenn's goal is to either let them maintain their weight or potentially lose one condition score over the season. They normally go in at 3.5-4 and come out at 2.5-3.

When they switched to organic their yields dropped but they have come back a bit since because of better management.

Like the division of crops and pasture land, the crops account for 60% of their income while cattle make up the other 40%. The crops normally produce more value per acre but the significant spike in beef prices has brought up their contribution. Glenn noted that up until 2008, prices for organic were really good but the price drop during 2009-2011 motivated a lot of producers to leave the market. Now, those that stayed are often getting paid 3 times conventional prices. Some of the younger farmers just weren't able to maintain their cash flow through the recession - having diversity and equity allowed Glenn and Nancy to stay in the game.

Infrastructure and Equipment

They have two storage sheds for machine storage and repair, 2 open front loose houses for livestock, and 11 grain bins with 17,000 bu of storage. There are aeration fans in most of the bins to make sure the grain freezes in winter to avoid insect damage. For their cows, there are corrals and open house sheds (for the calves), 3 heated watering bowls, 7 portable windbreak panels, lots of fence (10 miles of electric), and shallow buried pipelines out to some of the pastures.

Figure 3. A view of the corral and some of the equipment.

Their equipment includes a Bourgault air seeder and cultivator, a Case IH Deep Tiller, Morris Rod Weeder, Case IH swather and combine for harvesting, grain truck, grain trailer, and a mower conditioner to cut hay for the cows. There are also 3 tractors: Versatile 2375 (375 hp), Case IH 7110 (130 hp), and Case IH 5240 (100 hp).

Inputs and Labor

There are no fertilizers, pesticides, or composts imported onto the farm - only organic mineral and salt for the cattle. Glenn burns 25,000 L of fuel/year and in the last couple of years has spent $28,000/year in machine maintenance.

Glenn buys 50% of his seed from pedigreed conventional seed growers. Organic seeds have a lot of undesirable weeds and it's impossible to produce an organic crop that's clean enough. They are comfortable cleaning and saving the other 50% of the seed, since it isn't bringing any new problems onto the farm.

Glenn and Nancy both work year round and their son and daughter help out a bit in the summer. The farm takes 1 person at full time and another at almost full time (40 hrs/week) on average. For Glenn, things go from 60 hrs/week in the summer to 20-30 hrs/week in the winter. Nancy works closer to 20 hrs/week year round. They've wondered about taking on a foreign exchange student through the International Agricultural Exchange Program. A neighbor gets people from Sweden and Northern Europe.

Risk Management

They have crop insurance but they probably could get by without it. Recently, insurance has been useful with their acres that have been too wet to seed. Their wheat is insured as a conventional crop, which doesn't cover weed pressure while their oats and flax have organic coverage. The premiums are higher and the payouts lower for organic insurance, but the insurance does cover weed pressure. Overall Glenn thinks that Saskatchewan's organic insurance system is much better than Manitoba's.

Something inevitably goes badly every year, which makes the variety nice. The livestock gives them options if there's a crop failure without having to worry about exporting nutrients.

Natural

Weeds and Pests

Their main problem weed is Canada thistle, which decreases their crop yields and the cows don't like. Field dock has been a bit of a problem and gotten spread around by the tillage equipment but will disappear if the weather turns dry again. Quack grass is common on the farm but Glenn doesn't mind that much because the cows eat it and it provides erosion protection. There is some leafy spurge that has become established on one of the quarters as well. Two non-crop plants on the farm that Glenn values are milkweed and black medic. The milkweed is fairly neutral agriculturally but attracts butterflies and hummingbirds which is nice. The leguminous black medic grows on its own but is hard to clean out of flax. Wild mustard grows profusely in the wheat, and Glenn would like to give the wheat an advantage by chopping off the mustard heads. However, some of his best wheat crops of the season come from areas with the worst mustard pressure.

Figure 4. Wheat and some mustard, ragweed & Molly the dog.

They have had much less of an issue with foxtail barley (which have become prevalent because of the excess moisture) than zero-till farmers, especially those trying to minimize their spray use, because it's easy to control with cultivation.

Glenn manages the weeds with a number of strategies, including crop rotation, mowing them with a rotary mower, cutting and baling them for cattle feed, and row cropping with inter-row cultivation. He's had good thistle control success by using perennial forage (i.e. alfalfa) to eventually choke them out.

He acknowledges that his tillage regime is probably killing a lot of microorganisms compared to no-till but it's hard to say what effect the chemicals have on the soil life. Glenn does recognize that the weeds and cover crops help the soil and environment. Regardless, he doubts that the areas that have been flooded for the past couple of years have much soil life now. Tilling has been helpful in drying out the soil in the wet years but it will be detrimental when the weather turns dry again.

They don't have any major insect pest pressure on the farm. Grasshoppers are the only threat to crops, and only in dry years. Lice are the only cattle pest, which get treated with Ecto-Phyte (Agridynamics) that smells like citronella. Late winter (March) is the worst time of the year.

The main disease problem recently has been ergot, with quack grass being a carrier. Fortunately, it can be blended with high fusarium crops because they have less than other farms. Otherwise disease isn't a problem.

Biodiversity

The wildlife they have on the farm includes lots of deer, ducks, geese, coyotes, foxes, raccoons, rabbits, and skunks. They have some Sandhill Cranes as well that spend time south of the yard in the fall. Moose have occasionally started to come through as of 5 years ago. The flooding has reduced their gopher population, but muskrats, which disappeared in the very dry 80s, have been coming back after the flooding.

Since going organic, Glenn has seen more dung beetles, bees, and pollinators living on the farm. They also have what seems like a lot of earthworms in the garden and flowers. Their yard now has more birds than most other places, with species of butterfly that they haven't seen before. They aren't sure about consumer health, but organic production has definitely been healthier for the family.

For a long time, there was too little water on the farm but now there is too much. It would be nice to have a place to store the water entering into the property. Glenn noted that no beaver dams have ever washed away but millions of dollars in damage to the roads has been caused by floods in the last few years. A farmer in the neighborhood released beavers into his pasture to slow the movement of water, but the municipality still pays people to kill them at $50/beaver.

Advantages and Challenges

Organic has been paying well, especially lately even though conventional farmers look at their fields and can't imagine that's possible. Glenn also really enjoys the social aspect of the organic community. If he could go back, he would have switched to organic 10 years sooner and done it all at once rather than slowly transitioning over 5-6 years.

The main challenges have been technical: how to get the annual crops to beat the weeds, performing well in conditions that are too wet or too dry. When growing crops, timing is everything: ideally there are two weeks of dry weather after seeding because otherwise the weeds really take off. Generally though, overcoming the idea that you only want to see one thing growing out in the fields has been quite a struggle.

Motivation and Concerns

Glenn likes the organic farmer lifestyle, especially in that he doesn't get told what to grow or what to spray. He likes being challenged by the weed and fertility issues that come with organic farming. The farm has been a great place for the kids to grow up. They want the land to be as good or better when the next generation takes over

They aren't that worried about the sustainability of their farm practices but because the organic market is small the prices can be very volatile. It is also trouble keeping around enough help to get work done.

Glenn's main environmental concern is phosphorus depletion, although so far he's been able to grow good crops on land with virtually no available P. His best guess is that the buckwheat, sunflowers, and tillage radish are drawing phosphorus from deeper in the soil profile.

Perhaps more of an observation, Glenn pointed out that back in the late 70s and early 80s Roundup/Glyphosate was new, very expensive, and only used in extreme problem spots. If it were to go off the market tomorrow, Glenn thinks that most farmers wouldn't know what to do. The fact that people are using it all the time is only leading to more weed resistance.

Learning

Sources

Glenn looks for information wherever he can get it (especially for free). He's learned a lot from institutions, like his time at the University of Manitoba, MAFRD (Manitoba Agriculture, Food and Rural Development), and WADO (Westman Agricultural Diversification Organization). Field days and conferences have also been valuable, including the organic science cluster, Organic Connections in Saskatoon and Regina, and being a member on the OPAM board for 6 years. The internet is another source, with the Organic Agriculture Canada website as an example. He's also read lots of farm papers and found valuable information in an uncle's pamphlets from Manitoba Agriculture in the pre-chemical/fertilizer area that discuss plow-downs and cover crops.

OPAM is the most expensive certifying agency in Manitoba but they have a lot more interaction with their members - helping new people with the transition and with general agronomic education. OPAM has two general meetings/year, the fall finance meeting and potluck supper in the winter. They have at least one farm tour in the summer and a lot of information comes simply from networking and learning from other people in the business.

Laura Telford at MAFRD has been good at finding niche markets for crops and very helpful with marketing. She compiles a lot of information and shares what people are getting paid.

Glenn hasn't had that much success in convincing people to switch to organic. The rest of the family (Glenn has two cousins and his youngest brother who live very close by and farm conventionally) accepts it although they don't talk about it. They get a lot of support from retired farmers and their weed problems haven't enough of a problem to upset the neighbors. Glenn's nephew was quite interested...until he started working for the chemical company.

Interests and Experiments

Glenn likes experimenting, and even if something doesn't work at first he likes to try to tweak it. He is trying to apply some of the polyculture cover cropping practices of Gabe Brown, and has attended some day-long Holistic Management seminars. He would like to know more about soil fertility and microbiology. He's also interested in developing varieties that are suited to organic - he's growing an old variety of barley that matures 25 days earlier than others but doesn't have any disease resistance in wet years. The variety is so old they don't even know its name.

Hairy vetch is theoretically the best organic legume, but its hard seed doesn't all germinate during the first year. It's also hard to separate from his main crop, Red Spring Wheat, although the fact that it seems to work very well for people might make it worth trying. The hemp experiment resulted in 8 hours cutting and cleaning out the combine. It still has the potential to be a high paying crop and a newer combine might work better. He's also let half a quarter section flax field reseed itself. It came up 35% flax and 65% other plants. 7 years later you can still see the field division because of the weed seeds put into the seed bank that year.

Finally, Glenn's curious about whether a subsoiler could break up solonetzic blocks and whether those areas could then be colonized with plants.

Appendix A - Map

The yard is located in the main block of the farm, in the area where fields 3, 4, and 6a converge. The large creek runs south of the property.