Hedgerows at the UBC Farm

Group 25
Ian Keery, Stephanie Kung, Joan Leung, Bronwyn Smith, Nicole Stavro-Leanoff, Daisy Tam, Betty Tan, Mariko Takahashi

April 10, 2009
TA: Rosie Smit

Table of Contents:

Abstract:

Greenhouse gas (GHG) emissions are a significant concern to the University of British Columbia (UBC) as the global warming crisis continues to escalate. UBC is committed to becoming a carbon neutral community. The use of agricultural management at the UBC Farm is one possible method to attain this carbon neutral status. This paper describes how we, Group 25 of AGSC 450, took part in researching the role that hedgerows at the UBC Farm play as a carbon sink and contributing to biodiversity on the UBC Farm. Our methodology was based on extensive literature review and hands-on experience, pruning budwood trees at the UBC Farm. Through this process, a set of recommendations were formulated for the UBC Farm and the next year's AGSC 450 students.

Introduction:

The University of British Columbia Food System Project (UBCFSP) allows students to actively engage in a collaborative and highly integrative research project, to enhance food security and sustainability of the local food system. The UBCFSP hopes to increase awareness and educate as many individuals in the faculty and the community as possible, to support a sustainable campus. Student involvement and working alongside community partners from various sectors within UBC is a vital component of the project. A truly unique part of the UBCFSP is that it is an on-going, dynamic project whereby a student's work is preserved for the benefit of future students, allowing them to pick up the project from where it was left off. One of the primary focuses of this project is global climate change and its ecological and environmental implications. Understanding these implications is key to enhancing the sustainability on the UBC campus. As students taking part in this project, we focused on the

issues regarding the increased GHG emissions and how the UBC farm plays its role in promoting a carbon neutral community.

Map of our Paper:

This paper illustrates the combination of the theoretical and practical efforts of our research. The paper will briefly address climate change and describe the attempts made by the UBC farm to reduce GHG emissions through the establishment of hedgerows. This paper will also explain the methods involved in conducting our research, related background literature, our findings and group discussions. Finally, we will conclude with our recommendations and suggestions towards reducing GHG and improving sustainability. We hope that our effort will lay the groundwork for future students in their research. More importantly, we hope to heighten the awareness of the campus population and instill a greater commitment in them to preserve our planet.

Problem Statement:

Conventional agricultural production can be a large contributor to GHG emissions. Through production modifications and landscape-use changes, particularly through the use of hedgerows, a farm can act as a "carbon sink" to decrease CO_2 emissions. Proper management of agricultural soils allows for CO_2 sequestration, without reducing crop productivity. The establishment of hedgerows at the UBC Farm attempts to investigate how landscape diversity and sustainable management can effectively restore the loss of habitat, biodiversity, or essential ecosystem services. Through a hands-on approach, we wish to examine how hedgerow networks promotes biodiversity on the UBC Farm, how this biodiversity contributes to sustainability and

the potential of the UBC Farm acting as a "carbon sink."

Group reflection on vision statement:

The overarching goal of a sustainable food system is to protect and enhance the diversity and quality of the ecosystem and to improve social equity, whereby:

1. Food is locally grown, produced and processed.
2. Waste must be recycled or composted locally.
3. Food is ethnically diverse, affordable, safe and nutritious.
4. Providers and educators promote awareness among consumers about cultivation, processing, ingredients and nutrition.
5. Food brings people together and enhances community.
6. Is produced by socially, ecologically conscious producers.
7. Providers and growers pay and receive fair prices.

While all of the vision statement principles are not directly applicable to our investigation of hedgerow networks, they still play a key role in how the UBC Farm produces food and builds community. We believe that primarily statements 4 and 6 relate to our research focus of biodiversity, sustainable management, and the provision of essential ecosystem services through the establishment of hedgerows at the UBC Farm. Hedgerows at the UBC Farm can be used to demonstrate to other farmers the importance of landscape diversity, thereby acting as a valuable educational tool. Furthermore, as statement 4 describes, raising awareness regarding cultivation is an objective that the presence of hedgerows could fulfill. Hedgerows play a key role in the preservation of the natural landscape, especially in an agricultural setting through the

incorporation of more native species into the cultivated landscape. Producing food in a socially and ecologically sustainable manner, as statement 6 encourages, is also achieved through the presence of hedgerows at the UBC Farm. Without the presence of blooming perennial species located in the hedgerows, pollinator species would be absent or in low numbers, which would result in minimal fruit and vegetable production at the UBC Farm (Carter, personal communication, March 2, 2009). Moreover, the planting of budwood trees or other hedgerow plant species helps to prevent soil erosion and improves the overall structure and drainage of the soil (Walter *et al*., 2003). This protects the adjacent cultivated land, allowing it to be more productive. The ability of hedgerows to minimize soil erosion is fundamental to its ability to sequester and store carbon; thereby increasing the potential of the UBC Farm to act as a "carbon sink" (Albrecht and Kandji, 2003).

Through our studies in the Faculty of Land and Food Systems, we have been exposed to a variety of different paradigms. In our day-to-day actions we strive to be more ecologically conscious and understand that everything in our food system is interconnected. Our group shares an ecocentric view, recognizing the importance of ecosystem conservation and maintaining ecological processes through a diversity of life forms. By having this value assumption, we believe that although humankind is part of nature, each life form is unique and warrants respect regardless of its worth to humans (Lindenmayer and Burgman, 2005).

Methods:

Research for this project was conducted through literature reviews and personal communications with Tim Carter, Douglas Justice and Rosy Smit. Interviewing Tim Carter provided information regarding the use and purpose of the hedgerows currently in existence at

the UBC Farm. The hands-on component of the project, pruning budwood trees, was directed through instruction provided by Douglas Justice. He taught us of proper pruning techniques, common diseases found on the cherry trees and how to minimize the spread of these diseases. Rosy Smit assisted us by providing a comprehensive biodiversity document, discussing and answering our questions about the project, as well as coordinating our farm work schedule.

Research for compiling the background knowledge on biodiversity and carbon sequestration through the use of hedgerows was conducted through internet resources, journal articles and course material from Agroecology 460.

The focus of the hands-on component of our project was to conduct fieldwork on the over-grown and under-managed hedgerows, located at the UBC Farm. The first priority was to identify and flag trees, which were no longer alive. Non-living trees are subject to removal in the future, thus no further work was necessary. Secondly, we removed the undergrowth surrounding productive trees, including blackberry and suckers. Finally, we removed non-productive sections from living trees and pruned them to create optimal airflow, sunlight and budding opportunity for next season. Additionally, our pruning during the winter months produced scions, which are available for grafting purposes next season.

Proper pruning consists of two main types of cuts, which include the thinning cut and the heading cut. A thinning cut simply removes unwanted branches to increase air and light circulation. An important aspect to a thinning cut is to ensure the cut occurs at base of the branch instead of leaving a stub behind, which will become subject to disease. A heading cut is one that will interrupt the entire branch system. This cut is used to encourage the growth of fruiting spurs and side branches by activating the plant hormones and disrupting its vascular system. An important aspect to pruning multiple trees along a hedgerow is to minimize the

chance of disease transfer. For this reason, we disinfected our tools with rubbing alcohol before and after working on each individual tree.

Findings and Discussion:

Biodiversity Principles:

According to the BC Ministry of Agriculture (BCMA), there are eight essential principles to enhance the overall health and biodiversity of an agricultural system. These principles can be integrated into the UBC Farm's management plan to generate a more sustainable food production system while simultaneously improving the ecosystem. The following principles are excerpts from the BCMA document *Planning for Biodiversity: A Guide for BC Farmers and Ranchers* (2008).

The first principle addresses the importance of maintaining native habitat and species such as forests, riparian zones and grasslands as they are the most important contributor to biodiversity in the area. With regards to the UBC Farm, it is important to maintain the surrounding forests to conserve the native habitat for local wildlife. In addition, the forest surrounding the UBC Farm provides a refuge for wildlife from the current development of adjacent lands.

The second principle acknowledges that not all agricultural areas have the ability to preserve natural environments. Instead this principle encourages the implementation of semi-natural landscape features such as hedgerows, shelterbelts, and buffer zones. By including these semi-natural landscape elements, biodiversity is partially conserved while enhancing productivity of adjacent agricultural lands. The hedgerows currently at the UBC Farm consisting predominately of cherry trees (*Prunus spp.*) are attracting pollinators, which are essential for

farm productivity. Through the establishment of a fully connected hedgerow system, corridors can be created thus allowing the Farm to be integrated, rather than isolated from the surrounding landscape.

The type and amount of biodiversity present fluctuates depending on the location of the agricultural land and seasonality according to principle three. Since the UBC Farm is located in a temperate climate, it is capable of producing food year-round and thus the continued farm activities have a significant impact on local and migratory species.

Establishing a network of natural and semi-natural habitat in an agricultural setting is important for the avoidance of habitat isolation, as stated by principle four. This allows for uninhibited movement of wildlife from area to area without disturbing crops. As previously stated in the second principle, forming corridors across agricultural lands is necessary to avoid habitat segmentation.

Structural diversity, which is promoted by principle five, creates a variety of niches which will further enhance the biodiversity of the area. Incorporating tree, shrub, and herbaceous species is essential to provide sufficiently diverse habitat for the wildlife at the UBC Farm. Pruning allows a greater amount of niches to be maintained by allowing sunlight penetration to the understory as well as preventing overgrowth of larger plant species.

Principle six stresses the importance of proper soil management since the health of the ecosystem is directly dependent on the health of the soil. As a result of healthy soils, a healthy ecosystem can be sustained and thus supports a wider array of biodiversity. Hedgerows contribute to soil stability by decreasing erosion, which positively impacts adjacent agricultural lands by increasing their productivity. This improved soil stability is valuable to the sustainable production of food at the UBC Farm, as well as ensuring proper carbon cycling in the soil.

Ensuring a proper carbon cycle enables the farm to act as a net carbon sink.

As plant species diversity increases, the ecosystem is able to attract and maintain a greater diversity of higher trophic level species. By establishing diverse plant communities within the hedgerows and a variety of hedgerow types, the UBC Farm can successfully apply this principle.

Finally, principle eight discusses the hazards of invasive alien species towards both natural and cultivated landscapes. Principle eight further elaborates on the potential for alien species to undermine biodiversity. Invasive species, such as blackberries (*Rubus spp.*), are an ongoing concern that must be kept under control at the UBC Farm. These alien species provide management challenges to producing and maintaining species diversity of hedgerows.

Maintaining a high level of biodiversity requires strong managerial commitment. Adhering to these eight principles provides the framework for establishing and sustaining biodiversity in an agricultural landscape. The specifics vary depending on the farm and location, therefore the UBC Farm must adapt these principles to realize their educational and agricultural goals as they relate to biodiversity on the Farm.

Discussion on CO_2 sequestration:

Soils play the largest role in the global carbon cycle next to the oceans (Follain *et/ al*., 2007). Depending on how it is managed, soil can have the potential to become a valuable sink for atmospheric carbon dioxide and other GHG, or it can be an additional source of these gases (Follain *et al*., 2007). Shifting land use away from frequent tillage to infrequent tillage through such actions as the establishment of hedgerows increases the soil's ability to store carbon (Follain *et al*., 2007). Hedgerows are able to sequester and store carbon through large biomass

accumulation, both above and below ground (Falloon *et al*., 2004). They can also reduce soil erosion attributed to wind and water (Walter *et al*., 2003). Minimizing soil erosion is very important, as it is a major player in carbon soil dynamics (Albrecht and Kandji, 2003). Carbon stocks in the soil are drastically decreased when erosion takes place (Follain *et al*., 2007). According to Walter *et al*. (2003), hedgerows are vastly important in the storage of soil organic carbon (SOC). They estimated that hedgerows contribute between 13-38% of the total carbon stock in SOC storage (Walter *et al*., 2003). When frequently cultivated land is converted to hedgerows and tree strips, the level of carbon sequestration increases while the release of N_2O decreases (Falloon *et al*., 2004). This emphasizes the importance of hedgerows, since N_2O has a global warming potential 280 times that of CO_2 (Falloon *et al*., 2004).

The extent to which a hedgerow is able to sequester carbon is dependent upon its structure, tree species, biomass production, environmental influences, soil characteristics and management of the system such as pruning frequency (Albrecht and Kandji, 2003). Results from various studies (Walter *et al*., 2003; Follain *et al*., 2007; Albrecht and Kandji, 2003) indicate that SOC stocks may be locally significant, more so than on the landscape level, since the effect of soil carbon is limited to approximately 10m on either side of the tree lines. Also, the first 30 cm of the soil is where most SOC storage occurs (Follain *et al*., 2007; Walter *et al*., 2003). This storage amount decreases with increasing soil depth (Follain *et al*., 2007; Walter *et al*., 2003). However, this said, the presence of hedgerows can improve adjacent fields' soil characteristics**,** while indirectly increasing their carbon sequestration through improved crop productivity and reduction of soil erosion (Albrecht and Kandji, 2003). Hedgerow implementation is not a short-term, quick-fix for carbon sequestering, as estimates indicate that it may take 50-100 years for soil carbon to reach a new equilibrium (Falloon *et al*., 2004). As Falloon et al. points out, "[t]he

value of hedgerow and tree strips lies in their permanence – they are features of the landscape that will need to be preserved and maintained for long-term carbon sequestration, and to fully enhance ecological and amenity benefits" (p. 247).

Alone, implementation of agroforestry features like hedgerows on farms is not going to be the single solution for mitigating GHG (Albrecht and Kandji, 2003; Falloon *et al*., 2004). This is one strategy when in combination with others, will help contribute to a greater ability to sequester carbon dioxide, as well as to reduce the release of other GHG (Albrecht and Kandji, 2003; Falloon *et al*., 2004; Smith *et al*., 2000).

Hedgerows Pro's and Con's:

Traditionally any non-crop vegetation within a farming landscape was thought to be nothing more than a site to harbor pest species that would damage crops. This has slowly given way to the understanding that if managed correctly, these non-crop based areas can provide habitat for beneficial species and aid in the conservation of native species. While there is a fine line as to whether these non-crop areas are harboring pests or beneficial species, it is clear that they are not simply a source of problems for farmers (Paoletti et al., 1992). Instead, the onus is on the farmer to monitor and manage the non-crop areas in ways that benefit their operations.

If properly managed, hedgerows can act as a key form of non-crop habitat, providing many advantages to a farming operation. One of the primary benefits is that hedgerows provide areas for native plants, insects and animals to reside (Boutin et al., 2002 and Bunce & Hallam, 1993). This assists in maintaining both species and structural diversity within an environment. By allowing native plants to grow in these set aside areas, the natural structural system of plants are allowed to be established (Freemark et al., 2002). In doing so, this provides natural habitat

for many of the native insect and animal species to reside in, even throughout intensive agriculture sites. This further ensures that native species richness and genetic pools in plants, insects and animals are conserved to some degree (Boutin and Jobin, 1998 and Maudsley, 2000).

By providing habitat for natural pest predators within hedgerows, farmers can reduce the pressure placed on their crops due to pests (Altieri and Nicholls, 1999 and Best, 1983). Predatory insects, birds and small mammals inhabiting hedgerows can consume many common crop pest insects. Raptors can perch in the hedgerow and keep small mammal pests, mainly rodents, which can damage crops under control as well (Mitchell et al., 2000). Predatory mammals, such as coyotes or foxes, can also inhabit these areas, further Skeeping pest animals in check. This, combined with the predation of insects, helps ensure adequate pest control year after year. There will be a lag phase between predator populations and those of their target prey, in doing so they will remain in a dynamic equilibrium over time (May, 1972).

The presence of raptors and predatory mammals also has the effect of scaring away certain migratory bird species that could damage either summer or winter crops (Ribic and Sample, 2001). Even if the predator species are not visible or present, it has been shown that these migratory birds do not land in fields with forest borders or where the hedgerows are interspersed between them (Ribic and Sample, 2001). However, this mainly applies to grassland-favouring birds, while other bird species are attracted to the increase in shelter sites provided by hedgerows. Grassland-favouring birds have been shown to cause more extensive crop damage due to the fact that they move in such large groups (Owen, 2008). Also, grassland birds will consume cover crops over the winter, which can lead to significantly reduced crops the next year (Owen, 2008 and Fageria et al., 2005).

Hedgerows have also been found to play a key role in attracting pollinators (Goulson,

2002). By having native plant species present in hedgerows, there is a higher likelihood that plants will be blooming throughout the year, consistently attracting pollinators (Goulson, 2002). Certain hedgerows could also provide enough area to allow for the establishment of a hive. This is invaluable for many farmers as certain crop species require insect pollination to produce the desired crop. It also further enhances biodiversity and helps conserve wild populations of pollinators.

Evidence shows that the incorporation of hedgerows on farmlands contributes to reduced environmental degradation of cultivated fields (Kiepe, 1995 and Fujisaka, 1993). They provide superior water conservation due to tree roots going deeper into the soil than most crop plants; which also helps prevent soil erosion (Kiepe, 1995; Alegre and Rao, 1996). If hedgerows are both sufficiently dense and tall they can provide wind protection which assists in preventing loose top soil from being blown away. These attributes are positives both from a conservation standpoint and a financial one, as less inputs are needed to maintain crop yields (Alegre and Rao, 1996).

Plant species within hedgerows can also provide another source of revenue to farmers. Whether it is through native species that produce a saleable item or from intentionally planted vegetation, the farmer can further profit from this land (Fjuisaka, 1993). Hence, instead of fully taking land out of production, it is merely changing what the goal of the land is. Fruit trees, wild flowers, berry bushes and a number of other plant species can make up part of a hedgerow while simultaneously supplying an easily marketable product for the farmer. There are some concerns associated with ensuring that the product is simple to harvest and remains disease free. However, with some simple management changes, farmers can gain all the benefits of hedgerows without sacrificing their bottom line.

Although hedgerows can provide habitat, or act as another food source by using agriculturally inclined species; they can also simultaneously encourage pest population growth. Pest species can include insects, small mammals and birds (Rieux et al., 1999; Arnold, 1983). These pests can harm crops in a number of ways from directly killing the plants to reducing yields. Crops can also be harmed by diseases that are present in hedgerow vegetation. Moreover, hedgerows can harbour these plant diseases, which are then transferred to crops and reduce production (Koech and Whitbread, 2004). Given the close proximity of the hedgerows and crops, wind, rainfall, animal or insect vectors and dead debris are all capable of easily transferring diseases to crops (Koech and Whitbread, 2004). Therefore, hedgerows could potentially cost farmers in terms of production or by an increased budget for pest and disease control.

Hedgerows also take arable land out of primary production. While there can be benefits from soil conservation and subsequent increased crop yields or decreased inputs, these gains usually take years to occur (Alegre and Rao, 1996). Even if the hedgerows have plants in them that can be harvested, it is unlikely the returns from these will be as significant as those that could be received for having the land under normal cultivation. Hence, there is the potential for farmers to lose income by incorporating hedgerows into their fields as opposed to keeping the land for growing crops.

Recommendations:

Upon completion of thorough research and hands-on experiences with this project, our group has come up with a series of recommendations for the UBC Farm, as well as for future AGSC 450 students that will be continuing this project topic.

To the UBC Farm:

We suggest that the UBC Farm should continue managing the established hedgerows. The longer the hedgerows are managed and cared for, the healthier they will be and the greater the potential they will have to act as carbon sinks. The importance of the UBC Farm acting as a carbon sink should be emphasized to younger students, other undergraduates and the UBC Board of Governors. This is because many students are not aware of the significant role the UBC Farm has in the GHG emission reduction. Demonstrating how simple agricultural practices, such as the inclusion and management of hedgerows, can reduce carbon dioxide emissions is important. Moreover, the message that the UBC Farm is a symbol and connection to agriculture and sustainability should be conveyed.

To the Future AGSC 450 Students:

For future students, we recommend that they visit other farms to identify alternative efficient "carbon sink" systems that are being implemented. From there, students can evaluate whether the same methods can be applied to the UBC Farm. Furthermore, students can research beyond the scope of hedgerows and begin investigating other alternatives to natural farming structures, which can contribute to landscape biodiversity and reduce GHG emissions.

Most importantly, we suggest that the UBC Farm, students and faculty of the Land and Food Systems continue to work towards retaining as much of the UBC Farm diversity as possible. This includes a balance between forested areas, cultivated land and hedgerows to ultimately reduce the amount of GHG emissions. This will further contribute to achieving a carbon friendly campus and promote community involvement.

Group Reflection:

Our group was excited and enthusiastic about getting our hands and feet dirty, while also getting one step closer towards completing this project. However, we encountered multiple challenges and obstacles in order to actually complete this hands--on component of the project. Before heading to the field, one limitation we faced was that no previous years of AGSC 450 students had completed this type of project before. This meant that we were starting from scratch and had to determine which direction we wanted to take our project in, instead of continuing where last year had left off. In particular, we found scheduling the most difficult aspect, since we had to organize appropriate hours with our community partners and with each group member's individual class timetables. Even after an agreed upon farm session was reached, the weather conditions further complicated matters. Visiting the UBC Farm was highly weather dependant since pruning cannot be done in wet conditions. Since the weather was not cooperating, some of our group members had to reschedule their pruning sessions several times. Although we were unfamiliar with pruning and it took time for us to become comfortable with the process, it was an enlightening experience. During pruning, the blackberries were a particular nuisance as they often got in the way of pruning some of the cherry trees and caused some minor physical damage to some of our group members. Getting over the fear of the chickens also seemed to be a great obstacle for a few of our group members when we had to prune the trees located within the chicken coop area. Although minor, the chickens often pecked at our outerwear, which got in the way of efficient pruning.

Despite some of the minor hardships during our hands-on sessions, our group was able to obtain extremely valuable experience and knowledge upon visiting the UBC Farm and completing our food system project. For instance, we learned some pruning skills, while also

obtaining an understanding of how landscape diversity on the Farm contributes towards minimizing GHG emissions. The importance of quality pruning tools, as well as the frequent disinfection of the tools was also some of the valuable things learned from our sessions. Most importantly, the instructive and informative sessions given by Douglas Justice and the guidance provided by Tim Carter were extremely helpful during our visits to the UBC Farm.

Although we are unable to see the immediate ecological implications of pruning the cherry trees, we understand that it is something that has to be maintained over the long-run. It is difficult to measure the effectiveness of the hedgerows acting as a carbon sink. However, it would have been helpful if our research could have been more informative, regarding the magnitude that pruning sessions contribute towards overall GHG reduction. We were glad to know that our efforts towards physically maintaining the hedgerows could be identified. These physical improvements not only made aesthetic improvements to the bushes and trees, but will also make it much easier to maneuver tractors through fields, for future management of the farm. Furthermore, even though this hands-on part of the project was not exactly related to most of our groups' undergraduate degree focus, we found it was a great opportunity for us to explore something outside of our specializations.

Two of our group members, Bronwyn and Ian, had an extensive background due to their previous agroecology classes. This was very useful since they were able to share this information, teaching the other group members and giving us a basis to begin our research. For some of our members who are in the FNH program, this was an opportunity to do something very different. In most FNH classes we are not given the opportunity to have a hands-on component, as well as interacting with others outside of the classroom. We all enjoyed getting to know each other better while working in the field, as it is a more relaxed environment than a

lecture hall. Ultimately, this opportunity enhanced our abilities to work collaboratively as a team and become active participants in maintaining our sustainable agricultural system located on campus.

Taking a more local approach towards minimizing carbon gas emissions, and effectively integrating our ideas with our community partners was also a very valuable experience. Collectively, we agreed as a group that pruning and gaining hands-on experience on the UBC Farm was something that could not be experienced elsewhere during the course of our studies at UBC. Through promoting more sustainable agricultural practices, we were also reminded of the quality of learning we receive from being in the faculty of Land and Food Systems. We are looking forward to visiting the UBC Farm in the future to see the how our work has impacted the UBC Farm as a whole, and to see how much disease levels, pest infestations, the overall health of the hedgerows and growth levels of other native plant have changed. Overall, we highly encourage next years AGSC 450 students to experience and participate in the same or similar hands-on project to ultimately, promote the UBC Farm as a carbon neutral model, helping us move one step closer to a sustainable and ecologically-friendly community.

Conclusion:

The amount of GHG emissions that is currently being emitted into our environment is a contributing factor to the ongoing global warming crisis. To reduce GHG emissions, one of the efforts made by the UBC Farm is to implement various production practices. One of these implementations is the use and maintenance of hedgerows. Hedgerows contribute to enhancing biodiversity on the Farm. Their key role in preventing soil erosion allows for effective sequestration of $CO_{2,}$ thus their presence would ultimately allow the UBC Farm to become a

more effective carbon sink. Our group was able to assist with the hedgerow maintenance through pruning of overgrown and undermanaged budwood trees. Although it is difficult to see the immediate effects of our pruning efforts, we understand and appreciate the necessity of pruning with respect to the overall picture of reducing GHG emissions. Hopefully, in the near future, more attention can be brought to the UBC Farm in order to promote and increase awareness regarding the importance of hedgerows as they assist in reducing factors of global warming. Lastly, the UBC Farm could act as a role model for other farms, by demonstrating how management of conventional agricultural production could alternatively reduce GHG emissions, instead of being a key contributor.

References:

Albrecht, A. and Kandji, S.T. (2003). Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystems and Environment*, 99, 15-27.

Alegra, J.C. and Rao, M.R. (1996). Soil and water conservation by contour hedging in the tropics of Peru. *Agriculture, Ecosystems & Environment,* 57(1): 17-25.

Altieri, M.A. and Nicholls, C.I. (1999). Biodiversity, ecosystem function, and insect pest management in agricultural systems. In: Collins, W.W., Qualset, C.O. (Eds.), *Biodiversity in Agroecosystems*. CRC Press, Boca Raton, FL, USA, pp. 69–84.

Arnold, G.W. (1983). The influence of ditch and hedgerow structure, length of hedgerows and area of woodland and gardens on bird numbers on farmland. *Journal of Applied Ecology*, 20: 731-750.

Best, L.B. (1983). Bird use of fencerows: implications of contemporary fencerow management practices. *Wildlife Society Bulletin,* 11: 333–347.

Boutin, C. and Jobin, B. (1998). Intensity of agricultural practices and effects on adjacent habitats. *Ecol. Appl.* 8, 544–557.

Boutin, C., Jobin, B., Belanger, L., and Choiniere, L. (2002). Plant diversity in three types of hedgerows adjacent to cropfields. *Biodiversity and Conservation,* 11: 1-25.

Bunce, R.G.H., and Hallam, C.J. (1993). The ecological significance of linear features in agricultural landscapes in Britain. Pages 11-19 in R.G.H Bunce, L. Ryszkowski, & M.G. Paoletti, editors. *Landscape ecology and agroecosystems*. Lewis Publishers, Boca Raton, Florida.

Fageria, N.K., Baligar, V.C. and Bailey, B.A. (2005). Role of cover crops in improving soil and row crop productivity. *Communications in soil science and plant analysis,* 36(20): 2733-2757.

Falloon, P., Powlson, D. and Smith, P. (2004). Managing field margins for biodiversity and carbon sequestration: a Great Britain case study. *Soil Use and Management*, 20, 240-247.

Ferris, L., Best, J., Scholefield, H., Marques, J., Sawada, B., and Nemetz, P. (2007). Carbon neutrality and UBC: A first glance.

Follain, S., Walter, C., Legout, A., Lemercier, B., and Dutin, G. (2007). Induced effects of hedgerow networks on soil organic carbon storage within an agricultural landscape. Geoderma, 142, 80-95.

Freemark, K.E., Boutin, C. and Keddy, C.J. (2002). Importance of farmlandhabitats for conservation of plant species. *Conseration Biology*, 16: 399–412.

Fujisaka, S. (1993). A Case of Farmer Adaptation and Adoption of Contour Hedgerows for Soil Conservation. *Experimental Agriculture*, 29: 97-105.

Goulson, D. (2002). Conserving wild bees for crop pollination. *Food, Agriculture & Environment*, 1(1): 142-144.

Kiepe, P. (1995). No runoff, no soil loss: soil and water conservation in hedgerow barrier systems. *Dissertation*, Wageningen University.

Koech, E.K. and Whitbread, R. (2004). Disease incidence and severity on beans in alleys between Leucaena hedgerows in Kenya. Agroforestry Systems, 49(1): 85-101

Lindenmayer, D. and Burgman, M.A. Practical Conservation Biology. CSIRO Publishing, 2005, pages 20-22.

Maudsley, M. (2000). A review of the ecology and conservation of hedgerow invertebrates in Britain. *Journal of Environmental Management*, 60(1): 65-76.

May, R.M. (1972). Limit Cycles in Predator-Prey Communities. *Science*, 177(4052): 900-902.

Mitchell, W.A., Kuvlesky, W.P., Burks, D. and Martin, C.O. (2000). Hedgerow and Fencerow Management on Corps of Engineer Projects. Engineer Research and Development Center, Vicksburg, Massachusetts.

Owen, M. (2008). The damage-conservation interface illustrated by geese. *The International Journal of Avian Science*, 132(2): 238-252.

Paoletti, M.G., Pimentel, D., Stinner, B.R., and Stinner, D. (1992). Agroecosystem biodiversity: matching production and conservation biology. *Agriculture Ecosystems & Environment*, 40: 3–23.

Ribic, C.A. and Sample, D.W. (2001). Associations of Grassland Birds with Landscape Factors in Southern Wisconsin. *The American Midland Naturalist*, 146(1): 105-121.

Rieux, R., Simon, S. and Defrance, H. (1999). Role of hedgerows and ground cover management on arthropod populations in pear orchards. *Agriculture, Ecosystems & Environment*, 73(2): 119-127.

Smith, P. Powlson, D.S., Smith, J., Falloon, P., and Coleman, K. (2000). Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture. *Global Change Biology*, 6, 525-539.

Walter, C., Merot, P., Layer, B., and Dutin, G. (2003). The effect of hedgerows on soil organic carbon storage on hill slopes. *Soil Use and Management*, 19, 201-207.