

# **Community composition change of pollinating insects on farms enrolled in Alternative Land Use Services pilot project in Norfolk County, Ontario**

**Courtney Irvine**

## **Abstract**

Pollination services provided by insects are important in the biological functioning of ecosystems, and the sustainable future of agriculture. However, wild bee populations are declining globally, and anthropogenic land use is implicated as one likely cause. This paper investigates Alternative Land Use Services (ALUS), a novel non-profit, agricultural land use management program which pays farmers to provide environmental services; and its effect on wild pollinator communities. Pollinators were collected on ALUS and non-ALUS sites of participating farms in Norfolk County in 2011 and 2012, and comparative tests determined that there was no difference in abundance of pollinating insects between restored natural habitat and conventional agricultural land use, and that overall pollinator richness was higher on non-ALUS sites. However, ALUS sites showed higher taxa richness of bees, while divergent trends were observed in fly pollinator taxa. This is congruent with temporal and spatial trends which report the decline of bee diversity as well as the increase of flies in human-dominated landscapes. The ALUS pilot project in Norfolk County provides a practical example to evaluate the success of voluntary programs which seek to conserve biodiversity on agricultural lands and provide payment for the provision of environmental services.

## **Introduction**

### ***Pollination Systems***

Pollination is the process in vascular flowering plants whereby pollen is transferred from anthers to stigmas to fertilize ovules. This process of sexual reproduction is beneficial for many reasons. As plants are sedentary, they have evolved a variety of strategies for pollination, including the use of wind, water or animal pollinators. Animal pollinators are a wide-ranging functional group including mammals, birds and insects. Animal pollinators engage in mutualisms with flowering plants, and are estimated to account for 60-90% of pollination of angiosperm species (Kearns, Inouye & Waser, 1998; Kearns & Oliveras, 2009). Insects are the primary pollinators of much of the diversity of wild plants and crops (Potts et al., 2010), and are a diverse group including moths, butterflies, bees, beetles, and flies. The taxa of bees (Apoidea) has been the widespread focus of research of pollinating insects, but Kearns (2001) argues for further research of fly (Diptera) pollinators as well.

Pollinators such as bees and flies perform an important role in the biological functioning of communities and significantly affect the maintenance of wild plant diversity and broader ecological stability (Potts et al., 2010). Plant species may experience decreased or inferior pollination following changes in pollinator communities including declines in abundance, richness, diversity and functional group composition (Harris & Johnson, 2004). A decline in wild plant abundance due to pollination limitation will cause a reduction in abundance of floral resources which is the best predictor of pollinator abundance, illustrating the feedback of this relationship (Kearns & Oliveras, 2009). A decrease in population size of plants or pollinators may increase the short-term extinction risk of either mutualistic participant, as a result of environmental and demographic stochasticity (Harris & Johnson, 2004). This suggests the

decline of pollinating species can lead to a parallel decline of plant species and vice versa (Biesmeijer et al., 2006). Pollinators which exhibit specific habitat or pollen preferences are more susceptible to extinction risks due to resource specialization (Potts et al., 2010).

Plant-pollinator networks are complex, and more research is necessary to adequately evaluate their structure and functioning (Kearns et al., 1998). Relatively few plant-pollinator interactions are obligate in nature; rather, plant-pollinator connective webs vary temporally and spatially (Kearns et al., 1998). Potts et al. (2010) suggest that pollination networks are asymmetric and nested to achieve resilience to local extinctions via redundancy. Yet Hoehn et al. (2008) find that functional diversity of pollinator communities is related to pollination success. This complements other literature which suggests that biologically diverse assemblages function more effectively in ecosystems due to niche complementarity (Hooper et al., 2005; Cardinale et al., 2006). Brittain, Kremen and Klein (2013) find that diverse pollinator communities buffer pollination services from environmental changes. The disruption of plant-pollinator networks would have significant effects on the environment and human health.

### ***Pollination in Agriculture***

Pollinating insects are economically important as they affect crop production and food security (Potts et al., 2010). Klein et al. (2007) find that insect pollinators are essential for 13 internationally traded crops; 30 more crop species are highly dependent on insect pollinators; and insect pollination is moderately important for 27 other international crops. It is commonly suggested that insect pollination accounts for approximately one third of global food production (Klein et al., 2007). Pollination may be required for seed production (ex. alfalfa) or to increase the quality (ex. sunflower) or number (ex. caraway) of seeds; as well it may increase the number or quality of fruits (ex. squash) or ensure uniformity in crop ripening (ex. oilseed rape) (Kearns

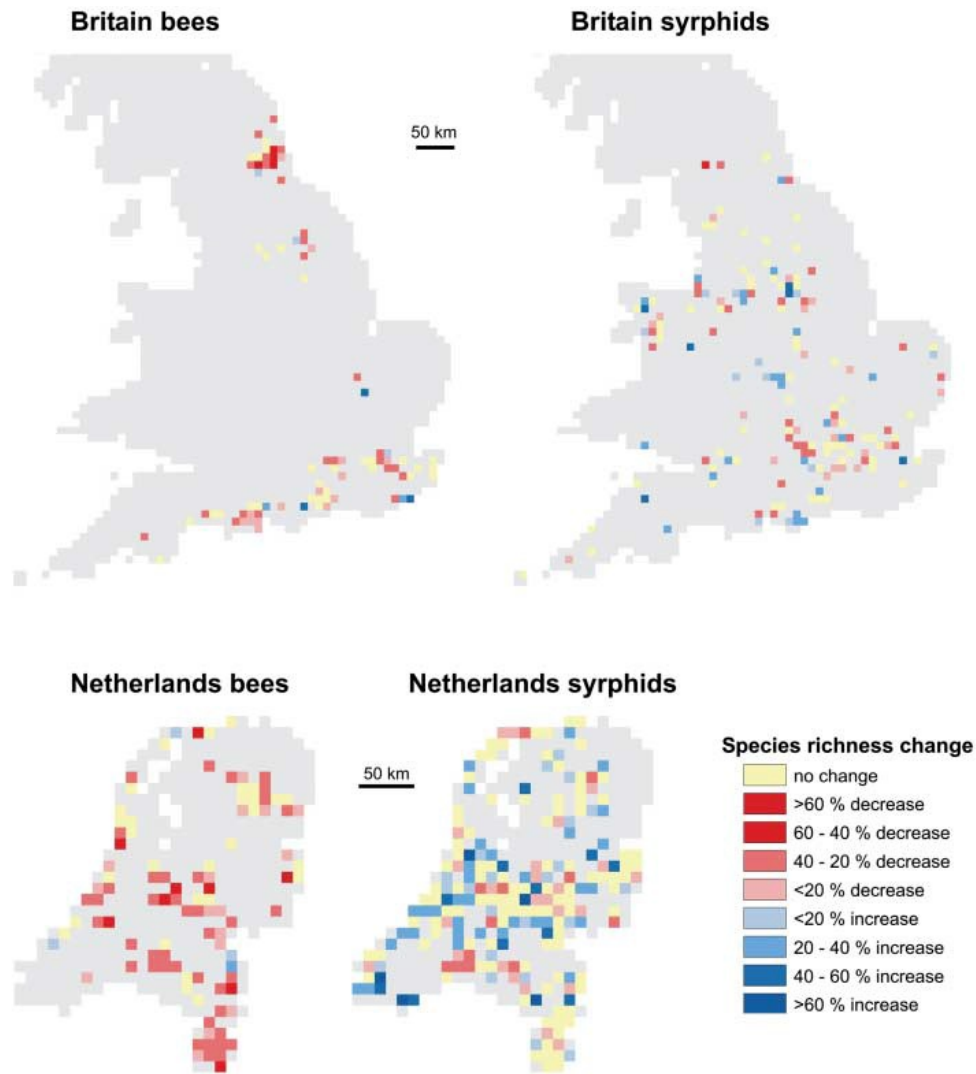
et al., 1998). Furthermore, pollination is the sexual reproduction of plants which enables gene flow, variety creation and adaptation in crops (Klein et al., 2007). Steffan-Dewenter, Potts and Packer (2005) argue the richness of the human diet depends upon pollination services. This is quantified by Eillers, Kremen, Greenleaf, Garber and Klein (2011), who find that 90% of vitamin C, all lycopene and almost all of the antioxidants  $\beta$ -cryptoxanthin and  $\beta$ -tocopherol, as well as the majority of lipids, vitamin A and related carotenoids, calcium, fluoride, and folic acid are found in crops that fully or partially depend on animal pollinators.

Despite the importance of pollination for crop production, there is a lack of information about how species diversity, abundance and community composition of pollinating insects affects fruit and seed yield, and productive quantity and quality of most crops (Potts et al., 2010). Many farmers rely on the 'free service' of wild pollinators, or use managed pollination services to compensate for a lack of pollinators (Potts et al., 2010; Biesmeijer et al., 2006). Managed honey bees (*Apis mellifera*) are very important in extensive and intensive agricultural as a cheap, versatile and convenient method of achieving pollination. However honey bees are not the most effective pollinators on a per flower basis for almonds, blueberries, watermelon, highland and lowland coffee, raspberries, blackberries, field tomatoes or cherries (Klein et al., 2007). Moreover, managed honey bees are facing serious threats from disease, including *Varroa* mites and *Nosema* fungus causing colony decline in North America (Currie, Pernal & Guzman, 2010), and evidence suggests commercial management of honey bees for pollination services is related to stress and nutritional deficit of colonies (Matila & Otis, 2006). The current dependence on a single species for pollination services indicates vulnerability in agricultural systems, and research and development applications have begun on diversifying this resource.

Howlett, Walker, Newstron-Lloyd, Donovan, and Teulon (2009) argue that understanding the role of unmanaged pollinators is critical if a robust and sustainable solution to declining honey bees is to be found, yet few studies assess the diversity, abundance and efficacy of unmanaged crop flower visitors on large spatial scales. Research indicates that pollination stability will increase with a diverse and abundant pollinator community (Klein et al., 2007). Species richness and functional diversity of wild bees is significantly correlated to increased seed production per plant in pumpkins (Hoehn et al., 2008). Species richness appears to enhance pollination efficiency through temporal and spatial complementarity in flower-visiting behaviour (Hoehn et al., 2008). Native bees and flies are the most abundant flower visitors of *Allium* and *Brassica* crops, though their relative importance and status as pollinators is not well understood (Howlett et al., 2009). Kearns (2001) asserts that more research on fly abundance, community composition and roles as pollinators is necessary to accurately assess the value of dipteran pollination.

### ***Pollinator Decline***

A review by Potts et al. (2010) suggests that wild pollinators are declining across the globe, and notes many possible causes including alien species interactions, climate change and habitat loss. Biesmeijer et al. (2006) find that local bee species richness in 10km<sup>2</sup> quadrants has declined since 1980 across Britain and the Netherlands, while hover fly (Syrphidae) species richness has increased (Figure 1).



**Figure 1: Change in bee and syrphid richness in Britain and the Netherlands before and after 1980 (Biesmeijer et al., 2006).**

Trait-based patterns of pollinator and plant decline were also noted by Beismejer et al. (2006): pollinators with narrow habitat requirements declined relative to those with wider habitat requirements; specialist pollinators relying on few plants as food sources declined relative to more generalist species; plants dependent on bee pollination have declined, while abiotically pollinated plants have increased, and plants dependent on self-pollination showed an intermediate response. These changes indicate a difference in community composition of pollinating insects over a large spatial and temporal scale in anthropogenic dominated

landscapes. It also documents an acknowledged link between pollinator and plant declines, and trait-based ecological groups at greater risk of extirpation events.

Anthropogenic land use is implicated as a potential major cause of pollinator community change and decline. A meta-analysis by Winfree et al. (2009) of 54 pollination studies on pollinators and anthropogenic land use found that habitat loss had a significantly negative effect on bee communities. This is caused by the loss or dissociation of food and nest resources (Hines & Hendrix, 2005; Potts et al., 2005). Different pollinator lifestages have different habitat requirements, and the requirements of different pollinators are not congruent; this increases the susceptibility of pollinator networks to disturbance (Harris & Johnson, 2004). The phenomenon of loss and fragmentation of pollinator habitats as a result of anthropogenic land use, and its effects on pollinator communities is under investigation by scientists worldwide.

Fragmentation and degradation of near natural and semi-natural areas prove to be detrimental to bee communities (Klein et al., 2007; Kremen et al., 2007; Steffan-Dewenter & Westphal, 2008; Cane et al., 2006; Ricketts et al., 2008). The concept of spatial scale and habitat fragmentation associated with land use intensification and pollinator abundance and richness is well explained in diagrammatic form by Steffan-Dewenter and Westphal (2008) (Figure 2).

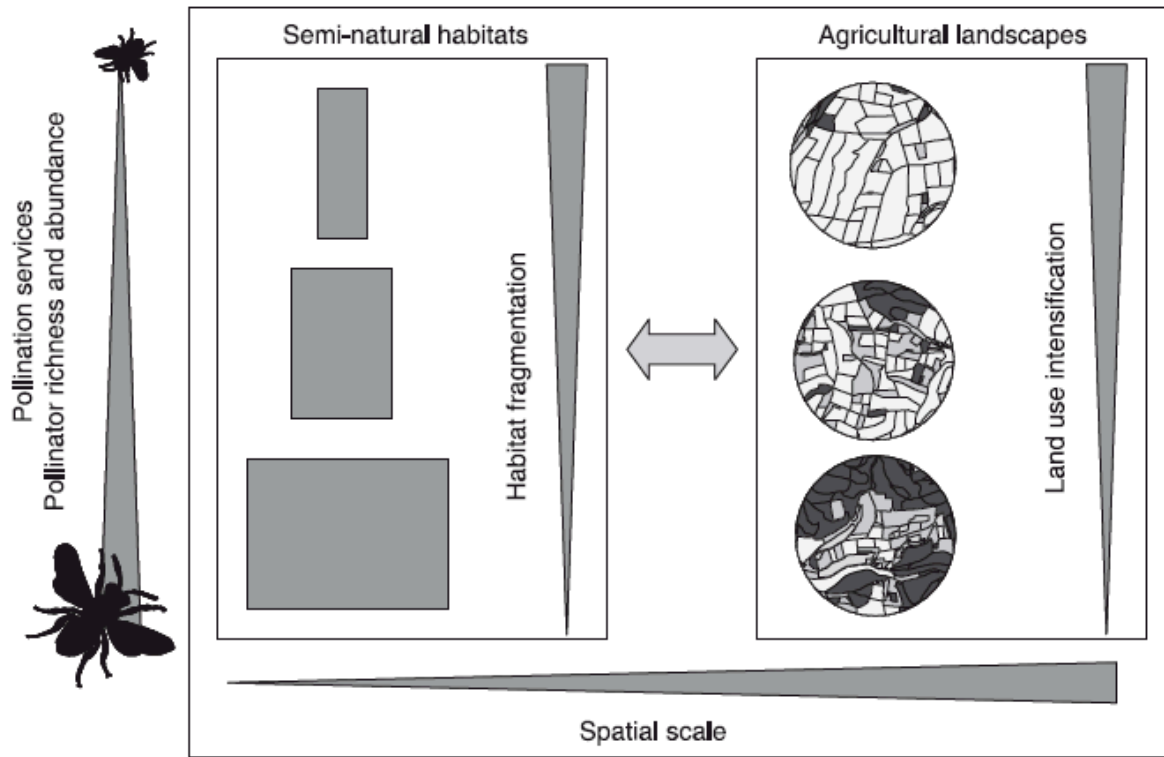


Figure 2: Interplay of pollination services, pollinator richness and abundance, and land use changes (habitat fragmentation and land use intensification) (Steffan-Dewenter & Westphal, 2008).

Kohler et al. (2008) find that the distance to high quality resources and habitats affects the reproduction success of pollinators, and thus population abundance over time. This may threaten the persistence of both pollinators and plant species (Harris & Johnson, 2004). Continuity of resources has proven to be important in pollination efficiency and success for wild and agricultural plants (Aguilar et al., 2006; Steffan-Dewenter & Westphal, 2008). Carvalheiro et al. (2010) find that wild pollinators of mango trees decline in abundance and richness with increasing distance from natural habitat areas. This result is echoed by a meta-analysis of 16 case studies that finds crop visitation rates decrease with increasing distance to pollinator habitats (Ricketts et al., 2008). Pollinator foraging behaviour is unknown for many insect species, and



thus it is hard to predict the effects of habitat fragmentation on pollination services (Stephan-Dewenter & Westphal, 2008).

Decline and change in pollinator communities threatens both ecological communities and sustainable agricultural production (Klein et al., 2007; Beisemeijer et al., 2006; Howlett et al., 2009). Bees have been the focus group for pollination studies, and literature review indicates that loss and fragmentation of habitat negatively affects their population dynamics. In the foreseeable future sole reliance on managed honey bees may prove problematic, and wild pollinators may provide an alternative source of pollination services. However, the value of these organisms as pollinators of agricultural flowering crops may depend upon the abundance and richness of the communities. Current practices in agriculture likely restrict populations of pollinating insects (Potts et al., 2010). Practices to provide improved habitat for pollinator communities within agriculture may provide both ecological and economic benefits.

### ***Innovative Solutions***

As agricultural lands continue to expand, increasing pressure on biodiversity comes from the simplification of landscapes to produce food, fibre and fuel (Cardinale et al., 2012). There are prominent arguments for the conservation and restoration of natural- and semi-natural habitats to increase and protect pollinator resources to improve natural pollination services (Klein et al., 2007). Conservation models have focused on providing areas of refuge for flora and fauna in the form of protected areas and parks (Banaszak, 1992). However, there is a recent shift which argues for the inclusion of humans in the natural environment and an integrated model of conservation (van Oudenhoven, Mijatovic & Eyzaguirre, 2011).

The discourse for the conservation of biodiversity within agriculture has become prominent, though not without conflict (Quinn, 2013). Banaszak (1992) claims biological

diversity of Apoidea can be maintained at a landscape scale if a mosaic of land use on agricultural lands occurs; this model includes a 25 percent buffer of non-farmed land as a refuge for native flora and fauna. Scherr and McNeely (2008) champion the ability of integrated eco-agricultural landscapes to host greater biological diversity of taxa groups including pollinators. The influence of natural habitat in agriculture on pollinator abundance and richness is becoming apparent within scientific investigation.

Frazen and Nillson (2008) find a positive correlation between decreased grazing pressure and species richness of three groups of pollinating insect: solitary bees, butterflies and burnett moths, in pastures of agricultural land in Sweden. Morandin, Winston, Abbott and Franklin (2007) find greater abundance of wild bees in canola fields with surrounding grazed pastureland versus surrounding tilled agricultural fields in Alberta, Canada. The abundance and species richness of pollinators as well as pollination services on nearby agricultural land was positively impacted by grassland extensification in Switzerland (Albrecht et al., 2007). Kearns and Oliveras (2009) find that ground-nesting bee species are positively correlated in abundance with the amount of grassland in nearby areas and with decreased grazing pressures in Colorado, USA. The spatial scale at which high-quality habitat improves wild pollinator populations appears to be relatively small (Kohler et al., 2008).

It is justifiably expected that restored or conserved natural spaces in agricultural landscapes will enhance the native pollinator community, likely with positive ecological and economic retributions. However, restored or conserved natural spaces are not productive for the farmer involved in their protection, thus are unlikely to occur without incentive (Quinn, 2013). Policies which provide incentives to provide biologically diverse landscapes in agriculture may increase the abundance and richness of pollinator communities. Providing incentives for the

conservation of biodiversity has come to be known as payment for environmental/ecosystem services or PES (Farber et al., 2006). Recognition of the services provided by biological diversity, as well as its distressing and imminent decline was asserted by the international community with the publishing of The Millennium Ecosystem Assessment in 2005. Schemes of PES attempt to include environmental services in economic decision making and have become a prominent tool internationally in private land initiatives for biodiversity conservation, especially within agriculture.

Alternative Land Use Services (ALUS) was the first program in Canada to assert a PES initiative. It began in the 1990s as a vision of the Keystone Agricultural Producers of Manitoba and Delta Waterfowl “to create a healthy, working landscape that sustains life support systems for agriculture, rural communities and wildlife” (ALUS, 2011*a*). Currently, farmers in selected regions may voluntarily convert up to 20 percent of marginal, less-productive or environmentally sensitive farmland to native vegetative cover or wetlands, and be paid an annual stipend in return (ALUS, 2011*a*).

ALUS secured support from the Canadian Federation of Agriculture in 2005 for pilot projects and the ALUS pilot project in Ontario began in 2007 (ALUS, 2011*b*). The pilot project in Norfolk County, Ontario began by interest from the Norfolk Land Stewardship Council with endorsement from the Norfolk Federation of Agriculture (ALUS, n.d.*a*) and is governed by a Partnership Advisory Committee (PAC) of local farmers and conservation stakeholders (ALUS, n.d.*b*). Norfolk ALUS administration holds information sessions about the program annually, and farmers submit an expression of interest to participate (ALUS, n.d.*b*). Every Norfolk ALUS farm project is developed in consultation between the farmer, the ALUS program coordinator and the Long Point Region Conservation Authority, and is reviewed by the PAC (ALUS, n.d.*b*).

Once approved, the farmer prepares the area for restoration, and is responsible for maintenance following ALUS site creation; the site is monitored annually by farmer liaison (ALUS, n.d.b). Farmers sign a 3 year contract with ALUS, but may opt-out at any time if payment is returned to the organization (ALUS, n.d.b). In Norfolk County, participating farmers receive \$150 per acre per year or \$75 per acre per year if secondary use of the ALUS site occurs (ALUS, n.d.b). The monetary incentive of Norfolk ALUS reflects the average cost of land rental in Norfolk County in 2007, not the estimated value of environmental services (ALUS, n.d.b). Funding is procured through a variety of sources, including public grants from the Ontario Ministry of Agriculture and Food, and private support, like the recently acquired \$1.5 million from The W. Garfield Weston Foundation (ALUS, n.d.b).

The ALUS pilot project in Norfolk County specifies four major ecosystem services to be provided by enhanced natural spaces on agricultural lands: wetland services, riparian services, upland services and wildlife enhancement services (Bailey & Reid, 2004). Wildlife enhancement services represent payment for the conservation of biodiversity. The conservation of biodiversity in Norfolk County is especially important because of the high volume of species at risk, the extensive use of land for agriculture, and the occurrence of rare Canadian ecosystems such as tall-grass prairie and Carolinian forest (Bailey & Reid, 2004).

Pollinating insects may be used as an indicator of wildlife enhancement services to be provided on ALUS farms. Strategically, they are a keystone ecological group in the conservation of biological communities (Harris & Johnson, 2004). As well, they are functionally beneficial in agricultural landscapes (Howlett et al., 2009). Lastly, there is a demonstrated correlation between anthropogenic land use and declining pollinator communities on a global scale (Potts et al., 2010). Thus, pollinator communities provide a link between the ecological and economic

benefits of voluntary biodiversity conservation initiatives on private agricultural land. This paper will investigate how pollinator communities are affected by farms participating in the ALUS pilot project in Norfolk County, and the implications of these results with regards to program development and environmental outputs, as identified by ALUS.

## **Methods**

### ***ALUS Restoration***

Four farms participating in the ALUS pilot project in Norfolk County were included in this study. ALUS restoration projects on the included farms began in 2008 and 2009. Each farm proceeded with a different ALUS restoration project according to local farm variables including soil conditions, moisture regimes and existing farm use. A description of the restoration projects of each farm is provided in Table 1 (personal communication with MacNeil, 2013).

<b>Farm</b>	<b>Data of restoration</b>	<b>Number of acres restored</b>	<b>Description</b>	<b>Species planted</b>
<b>A</b>	<b>2009</b>	<b>1.19</b>	- native flowering trees and shrubs planted in a hedgerow as a replacement to a traditional style windbreak. - nesting habitat provision for solitary pollinators was also included in this project (Horizontal holes were drilled into existing stumps).	25 <i>Quercus rubra</i> 200 <i>Quercus velutina</i> 100 <i>Prunus virginiana</i> 260 <i>Cornus amomum</i> 100 <i>Nyssa sylvatica</i> 190 <i>Corylus americana</i> 30 <i>Cornus racemosa</i> 59 <i>Cornus florida</i> 150 <i>Sambucus nigra</i> 10 <i>Amelanchier</i> sp.
<b>B</b>	<b>2008</b>	<b>0.94</b>	- planted wildflower seeds totaling 6.5 lbs in a plot adjacent to a crop operation requiring pollination services	<i>Lespedeza capitata</i> <i>Desmodium canadense</i> <i>Desmodium paniculatum</i> <i>Heliopsis helianthoides</i> <i>Verbena stricta</i> <i>Rudbeckia triloba</i> <i>Pycnanthemum virginianum</i> <i>Ceanothus americanus</i> <i>Oenothera</i> sp. <i>Scrophularia marilandica</i> <i>Penstemon hirsutus</i> <i>Penstemon digitalis</i> <i>Asclepias tuberosa</i>
<b>C</b>	<b>2009</b>	<b>6.36</b>	- reforestation project to emulate early successional forest cover on a steep slope near a riparian zone	45 <i>Acer saccharinum</i> 908 <i>Quercus rubrus</i> 75 <i>Populus tremuloides</i> 30 <i>Ulmus laevis</i> 43 <i>Pinus strobus</i>
<b>D</b>	<b>2009</b>	<b>35.17</b>	- planted grass to establish a Tallgrass Prairie ecosystem on a former agricultural field	<i>Andropogon gerardii</i> <i>Schizachyrium scoparium</i> <i>Sorghastrum nutans</i> <i>Panicum virgatum</i>

**Table 1: Description of ALUS restoration projects on Farms A, B, C, D provided by ALUS administrator Mark MacNeil in personal communication, 2013.**

### ***Data Collection***

Data was collected on each farm (A, B, C, D) on two occasions each in 2011, and on two farms (A and B) on four occasions each in 2012, between May and October. Each farm consisted of an ALUS experimental site, and a conventional agricultural (non-ALUS) site. During each sampling event, 8 yellow pan traps, 8 blue pan traps and one malaise trap were set up and left for 48 hours on both an ALUS site and a non-ALUS site. Pan traps are the most commonly deployed

sampling protocol of pollinators and consist simply of a coloured bowl filled with soapy water, to which insects are attracted by the colour and subsequently drown (Roulston, Smith & Brewster, 2007). The two pan trap samples were combined for storage in 90% ethanol. Malaise traps are tent-like structures which collect flying insects into 90% ethanol. They are widely used, especially for sampling of Diptera and Hymenoptera (Mazon & Bordera, 2008). The data was collected by Norfolk Environmental Stewardship Team (NEST) employees, a function of the Norfolk Land Stewardship Council.

### ***Specimen Identification***

Three taxa were chosen as representative pollinating insects: Apoidea, the superfamily taxa of bees; Syrphidae, the family commonly known as flower flies or hover flies; and Calliphoridae, another family of pollinating flies including blow flies and cluster flies.

Apoidea was chosen because it has been studied extensively, and it known to be the most important pollinating taxa (Potts et al., 2010). Bees were sorted to family or genus by members of the CANPOLIN laboratory at the University of Guelph using the dichotomous key “The Bee Genera of Eastern Canada” by Packer, Genaro and Sheffield (2007) and sent to respective experts for species identification. Because of time constraints, many bees included in the analysis remained at genus level.

Syrphidae flies were included as representative pollinators because they are commonly observed on flowers, and are increasingly included in pollination studies of natural systems (ex. Beismiejer et al., 2006). They are also understood to include the most important genus of pollinating fly in Ontario (Woodcock, 2012). Syrphidae flies were identified to genus or species by fly taxonomist Andrew Young, M.Sc. at the University of Guelph.

Calliphoridae flies were included because they are known to be common pollinators of a wide variety of plants, and are one of the most commonly observed families of insects on flowers (Marshall, Whitworth & Roscoe, 2010). Though less commonly included in studies of pollination systems, blow flies are suitable pollinators for vegetable seed production operations and are sold as Natufly® by Koppert (Woodcock, 2012). Calliphoridae flies were identified to species by the author using a dichotomous key to blow fly species by Marshall, Whitworth and Roscoe (2010) and a dichotomous key to cluster fly species by Jewisse-Gaines, Marshall and Whitworth (2012).

### ***Statistical Methods***

Taxa abundance and richness were used as proxies to measure differences in composition of representative pollinating insects between ALUS and non-ALUS sites on participating farms A, B, C and D in Norfolk County, ON. Abundance was calculated by recording the number of representative pollinating insects collected per sampling event at each site. A two-tailed paired sample t-test for means was used to determine if there was a difference in the average abundance of pollinating insects collected per sampling event between ALUS and non-ALUS sites ( $\alpha=0.1$ ). Sixteen data points representing sixteen sampling events were used in this analysis. This process was performed for representative pollinating insects altogether, and for each taxa (Apoidea, Syrphidae and Calliphoridae) individually.

Taxa richness was calculated by recording the number of different species or genera that were collected per sampling event at each site. Differences in taxonomic resolution were considered, and the highest level of clarity was used. For example, if all insects in a genus were identified to species, then each species was counted as one; however if only genus was identified, or only some specimens in the genus were identified to species, then all specimens in



the genus were counted as one. A two-tailed paired sample t-test for means was used to determine if there was a difference in mean taxa richness per sampling event between ALUS and non-ALUS sites ( $\alpha=0.1$ ). Sixteen data points representing sixteen sampling events were used in this analysis. This process was performed for representative pollinating insects altogether, and for each taxa (Apoidea, Syrphidae and Calliphoridae) individually.

Paired sample t-tests are useful in determining differences in abundance and richness of bees when each data point consists of two comparable entities. The data collected for this study fits this regime, as insects were collected on an ALUS site and a non-ALUS site on one farm for each sampling event, giving two data points for comparison.

## Results

The total number of pollinating insects included in the study collected over two sampling seasons was 854; 390 on ALUS sites, and 464 on non-ALUS sites. The total number of distinct taxa identified at the time of analysis was 55; 24 taxa of Apoidea, 22 taxa of Syrphidae, and 9 taxa of Calliphoridae (Table 2).

Genera/Species	Farm A ALUS Sites	Farm A Non- ALUS Sites	Farm B ALUS Sites	Farm B Non- ALUS Sites	Farm C ALUS sites	Farm C Non- ALUS sites	Farm D ALUS sites	Farm D Non- ALUS sites
Apoidea								
<i>Agopostemon</i>	1	1	4	3				
<i>Adrena</i>		3	1	2				
<i>Apis mellifera</i>		1	5					
<i>Augochlorella aurata</i>	27	4	29	7	6	3	4	2
<i>Bombus impatiens</i>	1	1	3					
<i>Bombus vagans</i>	1	1		1				
<i>Calliopsis andreniformis</i>		1						
<i>Ceratina</i>	10	4	14	6				
<i>Coelioxys sayi</i>	1							
<i>Halictus confuses</i>	5	1			6		1	
<i>Halictus ligatus</i>	1	1	2	1		1		
<i>Halictus rubicundus</i>	2							
<i>Hylaeus</i>					1			

<i>Lasioglossum</i>	47	57	61	44	9	30	18	9
<i>Megachile</i>			2	1	1	1		
<i>Melissodes</i>			1	5				
<i>Nomada</i>		2						
<i>Osmia distincta</i>		1						
<i>Osmia proxima</i>			1					
<i>Osmia simillina</i>	2		1					
<i>Peponapis pruinosa</i>			1					
<i>Pseudopanurgus nebrascensis</i>		1						
<i>Sphecodes</i>	7	6	8	3				
<i>Stelis lateralis</i>						1		
Syrphidae								
<i>Chalcosyrphus nemorum</i>		1		2		1		
<i>Chrysotoxum pubescens</i>			1					
<i>Eumerus</i>			6	18				
<i>Eupeodes</i>		1	1	4				
<i>Lejops</i>					1			
<i>Melanostoma mellinum</i>					1	1		
<i>Neoascia metallica</i>								1
<i>Ocyrtamus fascipennis</i>							1	
<i>Paragus haemorrhous</i>							1	
<i>Paragus</i>	1		1	1				
<i>Parhelophilus laetus</i>								1
<i>Platycheirus hyperboreus</i>		2		1		1		
<i>Platycheirus nearcticus</i>								1
<i>Platycheirus quadratus</i>		1				2		1
<i>Platycheirus scambus</i>		2						
<i>Platycheirus</i>						4		
<i>Sphaerophoria philanthus</i>				1				
<i>Sphaerophoria</i>	1	2		1		1		
<i>Toxomerus geminatus</i>		3	1	10		1	1	1
<i>Toxomerus marginatus</i>	15	35	12	71	21	29	21	12
<i>Trichopsomyia apisaon</i>		1						
<i>Tropidia quadrata</i>		1						1
Calliphoridae								
<i>Calliphora terreanovae</i>		6	1					
<i>Cynoma cadaverina</i>		1						
<i>Lucilia illustrus</i>		1		1				
<i>Lucilia silvarum</i>	2				1			
<i>Phormia regina</i>				1				
<i>Pollenia labialis</i>	2	4	1	1				
<i>Pollenia pediculate</i>	1		1	6		1		
<i>Pollenia rudis</i>	8	14		3	2	2		
<i>Pollenia vagabunda</i>				2	1			
Total Species Abundance	135	160	164	196	50	79	47	29
Total Species Richness	19	29	23	25	11	15	7	8

Table 2: Number of genera/species collected between May 2011 and October 2012, on ALUS and non-ALUS sites of Farm A, B, C and D.

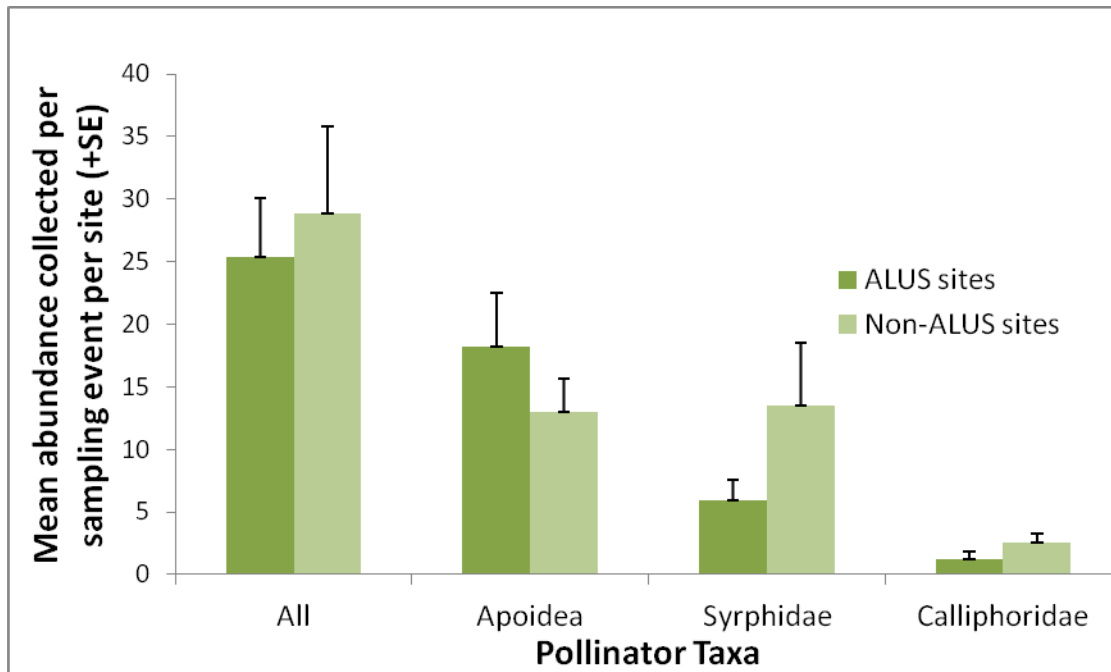


Figure 4: Mean abundance of pollinating insects collected per sampling event at ALUS and Non-ALUS sites on farms in Norfolk County, Ontario between June 2011 and October 2012.

The null hypothesis  $\mu_{ALUS} = \mu_{Non-ALUS}$  was accepted based on the data of abundance collected per sampling event for all insects ( $P=0.374$ ,  $n=16$ ), as well as for Apoidea ( $P=0.129$ ,  $n=16$ ) and Syphidae ( $P=0.117$ ,  $n=16$ ).

The null hypothesis  $\mu_{ALUS} = \mu_{Non-ALUS}$  was rejected based on the abundance of Calliphoridae collected per sampling event, which was significantly lower on ALUS sites (1.25) than on non-ALUS sites (2.688) ( $P=0.088$ ,  $n=16$ ).

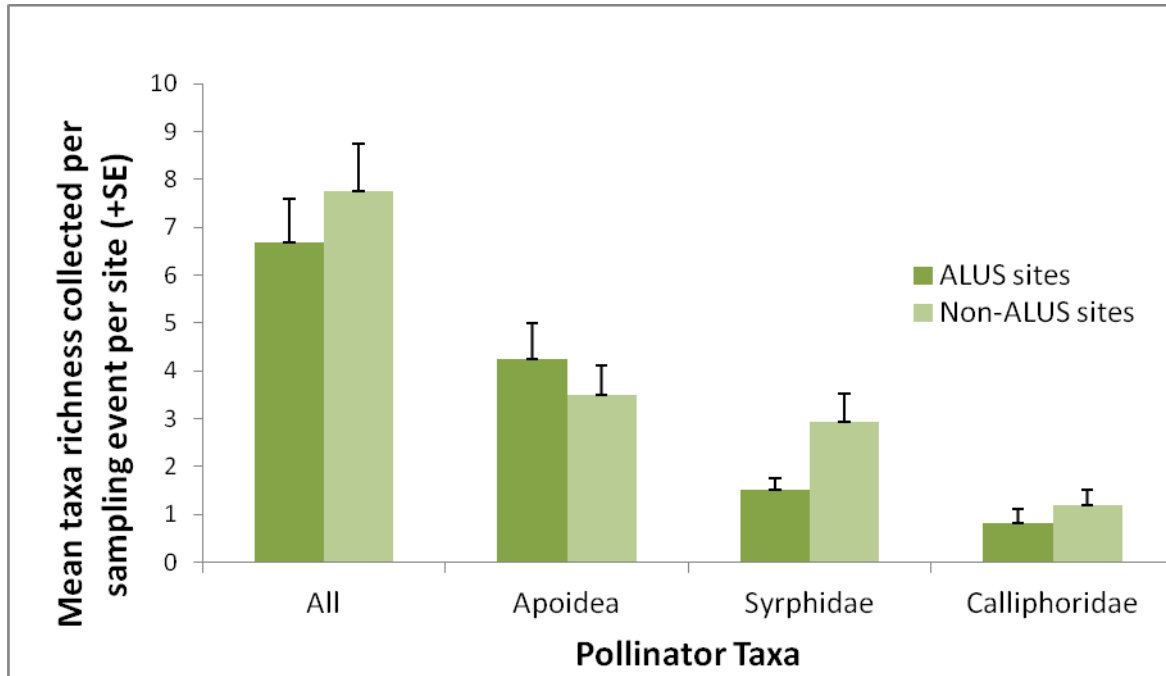


Figure 5: Mean taxa richness of pollinating insects collected per sampling event at ALUS and Non-ALUS sites on farms in Norfolk County, Ontario between June 2011 and October 2012.

The null hypothesis  $\mu_{ALUS}=\mu_{Non-ALUS}$  was rejected based on taxa richness collected per sampling event for all insects, Apoidea and Syrphidae. Pollinators overall were more rich on non-ALUS sites (7.938) than on ALUS sites (6.313) ( $P=0.032$ ,  $n=16$ ). The average richness of bees collected per sampling event was higher on ALUS sites (4.125) than on non-ALUS sites (3.438) ( $P=0.060$ ,  $n=16$ ). The average richness of Syrphidae collected per sampling event was lower on ALUS sites (1.375) than non-ALUS sites (3.188) ( $P=0.006$ ,  $n=16$ ).

The null hypothesis  $\mu_{ALUS}=\mu_{Non-ALUS}$  was accepted for the species richness of Calliphoridae collected per sampling event ( $P=0.119$ ,  $n=16$ ).

## Discussion

### *Pollinator Communities on ALUS farms*

Pollinators overall were not significantly more abundant and rich in ALUS areas of participating farms. This trend is divergent from scientific literature that suggests pollinator

abundance and richness is dependent on the availability of nearby natural space. Banaszak (1992) describes pollinator density as a gradient along the distance from natural forested areas. Holzschuh et al. (2011) theorize that mobile organisms in managed habitats benefit from neighbouring natural habitats which provide nesting resources or refuge from disturbance events. Ricketts et al. (2008) find a correlation between the distance to natural pollinator habitats and flower visitation rates. Thus increasing the availability of natural habitat was expected to increase the abundance and richness of pollinating insects.

Divergent trends for bee and fly pollinators were found when data were analysed according to taxa (Apoidea, Syrphidae and Calliphoridae). Bee pollinators were significantly more rich on ALUS sites than non-ALUS sites. The role of bees as efficient and effective pollinators of agricultural crops is well accepted (Klein et al., 2007). Because of their well-established role as pollinators, anthropogenic effects on pollinators are often quantified by bee populations (ex. Medan et al., 2011; Winfree et al., 2009). This may explain why the results for bee communities were congruent with trends in the literature which suggest that proximate natural habitat increases the taxa richness of pollinators.

Calliphoridae flies were significantly less abundant and Syrphidae flies were significantly less rich on ALUS sites of participating farms. Beismiejer et al. (2006) find that Syrphidae populations are richer now than prior to 1980 in the United Kingdom and the Netherlands. This suggests that fly pollinators may be well-adapted to landscapes which are dominated by anthropogenic use. There is no available literature on how anthropogenic land use affects Calliphoridae flies, despite being known important pollinators.

Rader et al. (2009) note there is a high degree of variability in pollinator response to different landscape contexts. This is likely due to the ecological differences, both within and

across taxa of pollinating insects (Winfree, Bartomeus & Cariveau, 2011). Many insects require a different habitat for each stage of development (egg, larvae and adult), and these requirements vary between species and genera. Resource provision for bees was targeted by Farm A, which included appropriate nesting habitat for solitary bees. As well, the provision of persistent and diverse floral resources was targeted by Farm A and Farm B, which is an important predictor of bee abundance and diversity (Winfree, Bartomeus & Cariveau, 2011). Targeting known habitat requirements for specific groups of pollinators may be most effective in increasing and diversifying their assemblage composition. Fly pollinator resources were not targeted by ALUS restoration projects, which may have affected their ability to moderate the population abundance and richness of fly taxa. However, the mechanisms which affect and predict fly population dynamics are relatively unknown (Kearns, 2001), so this may prove difficult.

Bees are known to be predominant pollinators, thus targeting this taxon is appropriate. All bees are florivores, both larval and adult stages feed on floral products, and bees often have specialized pollen gathering behaviour and structural adaptation (Winfree, Bartomeus & Cariveau, 2011). Pollinating flies only require floral resources as adults, and often seek nectar, rather than pollen (Winfree, Bartomeus & Cariveau, 2011). However, the relative importance of bee and fly pollinators is unknown for most plant species, and recent research implicates the undocumented importance of generalist flower-visitors, such as fly pollinators, in pollination services (Rader et al., 2009). Furthermore, both wild bee and fly species are found to be efficient pollinators of certain crop species (Rader et al., 2009). Pollinating bees and flies have been shown to be temporally complementary, and greater diversity of taxa is likely to improve pollination services (Rader et al., 2009). More research is needed to determine the relative importance of bee and fly pollinators to both wild and agricultural species of plants.

The literature is dominated by abundance and richness indicators of pollinator communities and these are the indices used in this study. However, Tylianakis et al. (2005) argue that these metrics do not capture changes in composition, such as the replacement of specialist species with generalist pollinators. The prospect of biotic homogenization is apparent among pollinator communities, as resource specialists have been proven to be most susceptible to decline and extinction (Winfree, Bartomeus & Cariveau, 2011). A diversity index would potentially clarify this aspect of pollinator community composition. Lastly, the mechanisms by which land use affects pollinator communities remain largely untested, thus it is difficult to distinguish causal and resultant population dynamics.

The differences in pollinator composition found in this study relate well to previous findings. Bee richness was positively impacted by ALUS projects on participating farms, and the trend in abundance also suggests likely difference with further investigation. Targeted resource provision and enhanced understanding of the mechanisms which predict population dynamics of bees is the likely cause. Fly pollinators were negatively impacted by the restoration activities in ALUS areas, which may relate to unknown mechanisms of land use and resource provision as predictors of population dynamics.

### ***Provision of Services***

The goal of the ALUS pilot project in Norfolk County was to test the feasibility of a farmer-driven approach to delivering social, economic and environmental benefits (Bailey & Reid, 2004). Two main objectives were identified for this pilot project: program development objectives, which are designed for building and testing the conservation delivery model in the community; and output objectives, which measure the impacts and/or benefits resulting from implementing ecological services in the county (Bailey & Reid, 2004).

Building and testing the conservation delivery model of ALUS may be assessed according to factors leading to participation in the pilot project. Participation in ALUS is voluntary, and is found to depend on three main factors: the creation of social capital and community encouragement, having a stewardship ethic, and the monetary incentive offered. These factors explicate participation in voluntary conservation initiative on private agricultural land which provides payment for environmental services (PES). Implementing ecological service delivery is assessed according to the provision and perception of environmental objectives, specifically wildlife enhancement services. The benefits of biodiversity are increasingly prominent with international support, and pollinators are illustrated as an indicator of such.

### ***Program Development Objectives***

Agriculture is a dominant land use in many developed countries, and Tilman et al. (2001) assert that it remains the driving force of land conversion in developing countries as well. Earl, Curtis and Allan (2010) note the urgency of addressing biodiversity loss on agricultural landscapes, as well as the fact that ownership of these lands is private. Failures and absence of state-centric, top-down regulation for the conservation of biological diversity on agricultural lands in Canada has led to the creation of voluntary, incentive-based programs, mainly the ALUS program and its Ontario pilot project.

Incentive-based programs provide motivation and opportunity for the conservation of resources on private land (Van Donkersgoed, 2005). An incentive reduces the burden of protecting natural assets on potentially profitable land. As one farmer participating in ALUS notes “I’d rather be proactive than be regulated” (Rosenberg, 2010). This indicates that the ALUS pilot project may have been forthcoming with a solution to an expected problem.



However, there are many factors which elucidate the participation of landowners in voluntary conservation initiatives. Raymond and Brown (2011) find that women, hobby farmers, well-educated people and those who have a high off-farm income are more likely to participate in private land conservation initiatives than other socio-economic groups. Furthermore, there may be area-specific differences in conservation opportunity and priorities (Raymond & Brown, 2011). Knowler and Bradshaw (2006) suggest there are few universal variables which regularly explain the adoption of conservation strategies in agriculture, and thus efforts must be targeted to local conditions. Broch and Vedel (2012) find that targeting contracts to the landowners' preferences will make initiatives for conservation on private land more effective in garnering support.

The ALUS pilot project in Norfolk County had acquired the participation of 94 out of 1651 possible farms in 2010, but reports full yearly capacity of 50 new participating farms in 2012 (Rosenberg, 2010). Moreover, over 1000 acres of marginal agricultural land was converted to natural vegetative or wetland cover by 2013 (Sonnenburg, 2013). The Norfolk ALUS pilot project was expected to conclude in 2012, but has been extended indefinitely, and in 2013 made plans to expand into 4 other counties in Ontario (ALUS, n.d.a).

It is important to discuss the factors leading to participation in the ALUS pilot project as they indicate community response to the delivery of the conservation model. There are three main factors discovered by Rosenberg (2010) through focus groups and interviews which underlie participation in the ALUS pilot project in Norfolk County. The first is community encouragement, the second a stewardship ethic, and third is the monetary incentive provided. These factors will be explained using examples from Rosenberg's (2010) study, and compared to

findings by Lantz (2012) who investigated the factors to participation in the ALUS PEI project, which is implemented province-wide.

The first underlying factor to participation in the Norfolk ALUS pilot project is community encouragement. This can be explained as understanding the ecological and economic benefits of increased biodiversity provided by conserved or restored natural landscapes. With specific reference to Norfolk County, Van Donkersgoed (2005) argues that the key to success for the ALUS pilot project will be the recognition that environmental services are real products with real value to society. Rosenberg (2010) argues this recognition is a direct result of community partners or creation of social capital. Social capital is defined as “informal social networks of relations; and the beliefs and norms to which these relations arise and define the character of networks” (Lewis and Chamlee-Wright, 2008). The exchange of knowledge between stakeholders including farmers, ALUS administration, municipal and provincial government, other country-dwellers, consumers representing the general public, and partnership organizations facilitates the creation of social capital (Rosenberg, 2010). Outcomes of knowledge exchange often influence how the goals and objectives of a project are defined between stakeholder groups (Fazey et al., 2012). Since environmental management is a process involving complex dynamics between natural and social systems, knowledge and recognition from a wide range of actors is required.

To begin the ALUS pilot project, a group of diverse stakeholders met 6 times to develop the draft pilot project proposal (ALUS, n.d.c). Following that, a benchmark survey was distributed to determine public opinion of the relationship between the environment and farming (ALUS, n.d.c). Norfolk ALUS has developed partnerships with many local organizations including Norfolk County, the Long Point Region Conservation Authority, Norfolk Federation of

Agriculture, Long Point Wetlands and Waterfowl, Bird Studies Canada, Picasso Fish, and Underhill Farm Supply. Most importantly, the agricultural community of Norfolk County is involved in the ALUS Partnership Advisory Committee (8/16 members) which oversees the development of ALUS projects (Rosenberg, 2010).

The development of social capital as precedence to participation in the ALUS pilot project in Norfolk County was investigated by Rosenberg (2010), who finds that ALUS acts as a broker (or intermediary) of social capital between those who supply environmental services (farmers) and those who demand them (funders). In this model, the value of environmental services is more likely to be distributed in the social and market economy (Rosenberg, 2010). The ALUS pilot project methods to engage public support (and create social capital) included: demonstration farms, farm tours, various conferences and workshops, marketing to the agricultural community via word of mouth, and farmer liaison targeting lands of specific ecological interests (Rosenberg, 2010).

In Norfolk County, farmers explained that their participation stemmed from hearing about the ALUS project from a neighbour, or being curious about ALUS signs at farm gates (Rosenberg, 2010). As well, they stated that the farmer-farmer approach of ALUS was an important facet of the program which encouraged participation, as it made ALUS feel like a community activity, rather than an introduced project (Rosenberg, 2010). Lantz (2012) found that community recognition was the number one reason farmers participated in ALUS PEI, while lack of awareness was the number one reason why they did not, and that more information on the impacts of farming on environmental systems would solicit more participation. These results suggest that a community understanding and ability to interpret and disseminate information regarding the ALUS program and project value is a critical factor to garnering participation.

The second factor underlying participation in the ALUS pilot project in Norfolk County unearthed by Rosenberg (2010) is having a stewardship ethic. This is defined by Turner and Daily (2008) as values which reflect precaution and guarantees the endowments of natural capital to future generations. A stewardship ethic may also be the result of previously generated social capital for those values.

Norfolk County is home to many rare species of Canadian wildlife and the rare biome of Carolinian forest; it also has the highest concentration of Species at Risk in Canada (Bailey & Reid, 2004). Thus there are a number of recovery planning and implementation projects within the county, which often include stewardship activities, habitat protection and restoration, monitoring, research and public information (Bailey & Reid, 2004). Vast amounts of information on the resources of Norfolk County have been collected by a variety of organizations, including but not limited to, Canadian Wildlife Service (CWS), Canada Centre for Inland Waters (CCIW), Ontario Ministry of Natural Resources (OMNR), Bird Studies Canada (BSC), Long Point Waterfowl & Wetlands Research Fund (LPWWRF), Ducks Unlimited Canada (DUC), Norfolk Field Naturalists (NFN), the Long Point Region Conservation Authority (LPRCA), and the Norfolk Stewardship Environmental Team (Bailey & Reid, 2004). Finally, the UNESCO Long Point Biosphere, established in 1986, resides within Norfolk County. Social capital regarding conservation values likely existed in Norfolk County prior to the implementation of ALUS as a result of these external interests.

Many participants of the ALUS projects in Norfolk County and in PEI were environmentally inclined, with an Environmental Farm Plan in place, or with overlapping practices to ALUS projects (Rosenberg, 2010; Lantz, 2012). Furthermore, participants and non-participants in Norfolk County illuminated that it is a “certain type of farmer” who engages in

the ALUS projects (Rosenberg, 2010). Characteristics of this farmer included facing pressure from younger generations on the farm, reporting personal life satisfaction from environmental projects, and noting observable differences and positive changes on farms as a result of ALUS projects (Rosenberg, 2010). The stewardship ethic or “greater good” was the second-most reported reason for participation in ALUS in PEI, and non-participants stated that being a good steward for the land would be a reason for participation in the foreseeable future (Lantz, 2012). Thus having a stewardship ethic is an important precedent for participation in ALUS projects, and may be enhanced by the a priori development of these values in an area.

Lastly, the monetary incentive provided by ALUS for restoration and the annual payment for environmental services (PES) was noted by farmers in both Norfolk County and PEI as an important factor leading to participation (Rosenberg, 2010; Lantz, 2012). Many participating farmers in Norfolk County noted that covering the costs of conversion of land was enough of a monetary incentive, while non-participating farmers stated that farming was a tough career and they couldn’t afford to lose productive space for conservation (Rosenberg, 2010). 47% of non-participants in PEI responded that increased financial incentives would convince them to become involved in the ALUS project (Lantz, 2012). Thus, the financial incentive and economic retribution provided by the ALUS projects are an important factor which provides opportunity for stewardship and garners support from farmers. The PES scheme of ALUS is a novel initiative in environmental governance, and deserves further investigation.

Ninety-five percent of land in Norfolk County is privately owned, yet publically owned wildlife, air and water traverse private land (Table 3).

Resource Ownership on Private Lands		
Resource	Private	Public
Soil	X	
Water		X
Crop	X	
Wildlife		X
Fish		X
Livestock	X	
Trees	X	
Air		X

**Table 3: Private and public resources on private lands (Bailey & Reid, 2004).**

The advent of value for environmental services represents the integration of ecology and economics, to explain the effects of human policies and land use on ecosystem function and human welfare (Farber et al., 2006). Moreover, environmental services represent the benefits human receive, directly or indirectly, from ecosystems (Constanza et al., 1997). PES schemes represent public acknowledgement of local and public benefits which arise from the maintenance of natural ecosystems (Farber et al., 2006).

Pirard (2012) cites an influential passage from the initiative on The Economics of Ecosystems and Biodiversity (TEEB ) to explain the phenomenon of PES from an environmental governance perspective:

“Market-based instruments, such as taxes, charges or tradable permits can, if carefully designed and implemented, complement regulations by changing economic incentives, and therefore the behaviour of private actors, when deciding upon resource use. When set

at accurate levels, they ensure that the beneficiaries of biodiversity and ecosystem services pay the full cost of service provision. Experience shows that environmental goals may be reached more efficiently by market-based instruments than by regulation alone. Some market-based instruments have the added advantage of generating public revenues’’

This passage notes the usefulness of PES on private lands, and their increasing popularity as governance tools (Pirard, 2012). However, methods of PES are variable and the scope and efficacy of these programs is yet unknown (Muradian et al., 2010).

ALUS is the first PES program in Canada. Muradian et al. (2010) would consider ALUS projects to be genuine PES whereby i) the relationship between land use being promoted and the provision of ecosystem service is clear, ii) stakeholders have the possibility to terminate the contractual relationship (transactions are voluntary), and iii) monitoring accompanies the intervention, to ensure that the provision of services is taking place. This designates the ALUS program as a practical example of the original conceptual model for PES.

However, funding for ALUS is unstable as it depends on yearly grants and private/public investment. One of the research objectives of the Norfolk ALUS pilot project was to determine the potential for new market opportunities for ALUS producers, however this remains unknown. Furthermore, annual payments are simple to administer and familiar, but unattached to outputs and costly over a long-term time scale (Campbell, 2009). There are other strategies for payment for the PES, each with benefits and costs (Table 4).

Policy Option	Advantages	Disadvantages
Regulation	<ul style="list-style-type: none"> <li>• Objective-driven</li> <li>• Equitable</li> </ul>	<ul style="list-style-type: none"> <li>• Involuntary</li> <li>• Costly enforcement</li> <li>• Arbitrary rules</li> <li>• Does not take advantage of the stewardship ethic</li> <li>• Inefficient</li> </ul>
Annual Payments	<ul style="list-style-type: none"> <li>• Simple to administer</li> <li>• Familiar</li> </ul>	<ul style="list-style-type: none"> <li>• Payment not attached to output</li> <li>• Costly, creates long-term commitment</li> <li>• Capitalization into land prices</li> </ul>
One-time Payment	<ul style="list-style-type: none"> <li>• Simple</li> <li>• Familiar</li> </ul>	<ul style="list-style-type: none"> <li>• Arbitrary parameters</li> <li>• Not linked to market opportunities or costs</li> </ul>
Auctions	<ul style="list-style-type: none"> <li>• Efficient</li> <li>• Equitable</li> </ul>	<ul style="list-style-type: none"> <li>• Costly to administer</li> <li>• Little experience in Canada</li> <li>• Not feasible for all EG&amp;S</li> </ul>
Tradable Permits	<ul style="list-style-type: none"> <li>• Efficient</li> </ul>	<ul style="list-style-type: none"> <li>• Needs agreements among diverse stakeholders</li> </ul>
Tax Incentives	<ul style="list-style-type: none"> <li>• Existing policy instrument</li> <li>• Voluntary</li> </ul>	<ul style="list-style-type: none"> <li>• Driven by tax reasons, not service to public</li> <li>• Cost not always linked to beneficiary</li> </ul>

Table 4: Advantages and disadvantages of different policy options for PES schemes (Guerro, 2010).

Another option to ensure funding for ALUS projects would be the creation of policy which asserts for PES, as other countries have done. The longest running policy for PES in agriculture is in the United States. The United States Farm Bill of 1985 created the Conservation Reserve Program which encouraged farmers to retire erosion-sensitive land from production in return for acre-based grant payments (Sullivan et al., 2004). It has resulted in a cumulative total of 33.7 million acres of land in 2009, representing approximately 3.7% of total cropland in the US, and costing \$1.9 billion annually (United States Department of Agriculture, 2010). In 1990, an Environmental Benefits Index was introduced to target multiple environmental objectives, and



applicants were ranked, accepted and paid based on anticipated environmental benefits (Smith, 2000). Some contracts were 5 years long, while others were indefinite (Guerro, 2010).

There have been attempts to push both Canadian provincial and federal governments to implement the ALUS program as policy, but they are currently fruitless. One exception is the province-wide implementation of ALUS in PEI, under the governance of the Provincial Department of Environment, Energy and Forestry. There are organizations which support the creation of ALUS policy in Ontario, known as the Ontario ALUS Alliance (ALUS, n.d.a). The government supports the ALUS program with yearly grants from a multitude of sources, but is unwilling to provide the structure and funding to implement it permanently.

Thus though ALUS is a novel, valid and valuable attempt to protect biodiversity and attach value to environmental services, the future of ALUS is uncertain. The program development of Norfolk County has proceeded smoothly and represents a classic PES scheme, however it may encounter funding issues. Doubts of the longevity of the program were one of the main deterrents to participation in ALUS programs, and may indicate a general lack of trust in agri-environmental initiatives (Rosenberg, 2010). This presents a difficult and important caveat to the Norfolk ALUS pilot project, and expansion projects in other counties in Ontario.

### ***Output Objectives***

In 1992, the United Nations held the first ever convention on biological diversity. In the Millennium Assessment of 2005, biodiversity was acknowledged to be negatively affected by human activities including agriculture, and actions for its protection were recommended.

Biodiversity was also acknowledged as a determinant for social and economic stability, social welfare, poverty reduction and adaptation to climate change by the European Commission (Turner et al., 2012). The UN designated 2011-2020 as the decade for biodiversity (United

Nations, n.d.). It is evident that the international governance community is interested in current global declines in biodiversity and strategies for protective action.

Agriculture restricts biological diversity with the goal of simplifying natural systems to maximize production of food, fodder and fuel (Van Donkersgoed, 2005). Other supporting and regulating environmental services (including water quality, nutrient recycling, pollination, etc.) provided by landscapes decrease when intensive production is demanded in the environment (Bennett, 2013: Presentation at the University of Guelph, March 26). This is the functional situation of most agricultural landscapes in the developed world.

The contribution of biodiversity to environmental processes is relatively well-established (Luck et al., 2009). Kremen (2005) identifies key environmental service providers characterized by functional traits of populations, communities, guilds and networks of interacting organisms. All environmental services are generated from myriad interactions occurring in complex systems, thus managing and measuring these services is difficult (Figure 6) (Luck et al, 2009).

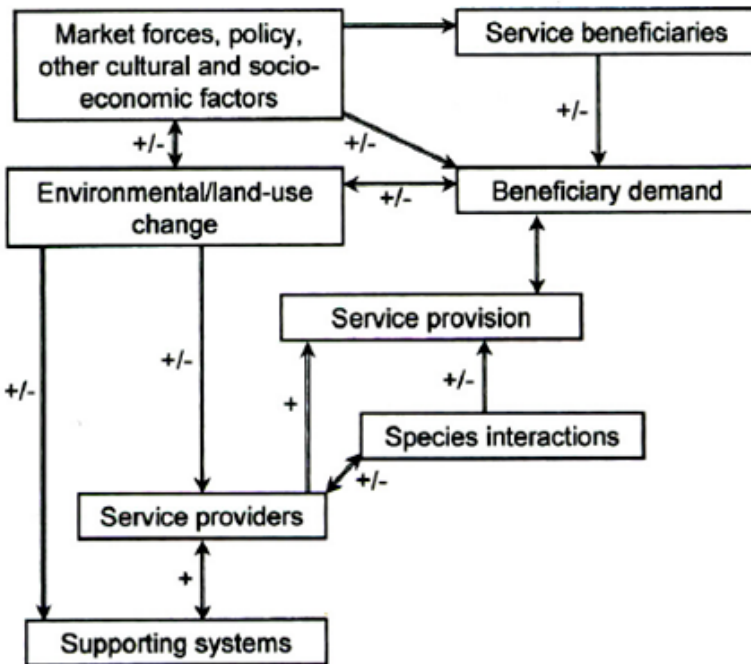


Figure 6: Conceptual model demonstrating the linkages between socio-economic and ecological factors to environmental service provision (Luck et al., 2009).

Environmental services are not included in traditional market economies, and preserving biological diversity which provides them was not considered an investment in past management strategies (Fromm, 2000). However, recent attention to environmental services provided by biologically diverse natural systems has garnered attempts at economic valuation and market inclusion (Fromm, 2000). The most famous study on the issue of pricing biodiversity and ecological services is by Constanza et al. (1997), who estimate the value of the biosphere to be \$33 trillion annually. Though this number is not useful; scientists, policy-makers and the general public find the attempt to place monetary value on natural ecosystems extremely appealing, especially with regards to conservation and environmental management activities (Gatto & De Leo, 2000). Farber et al. (2006) suggest that valuation attempts are most successful when considering the local context of biodiversity and environmental services. Yet these attempts are few and far between, and none exist for Norfolk County, Ontario.

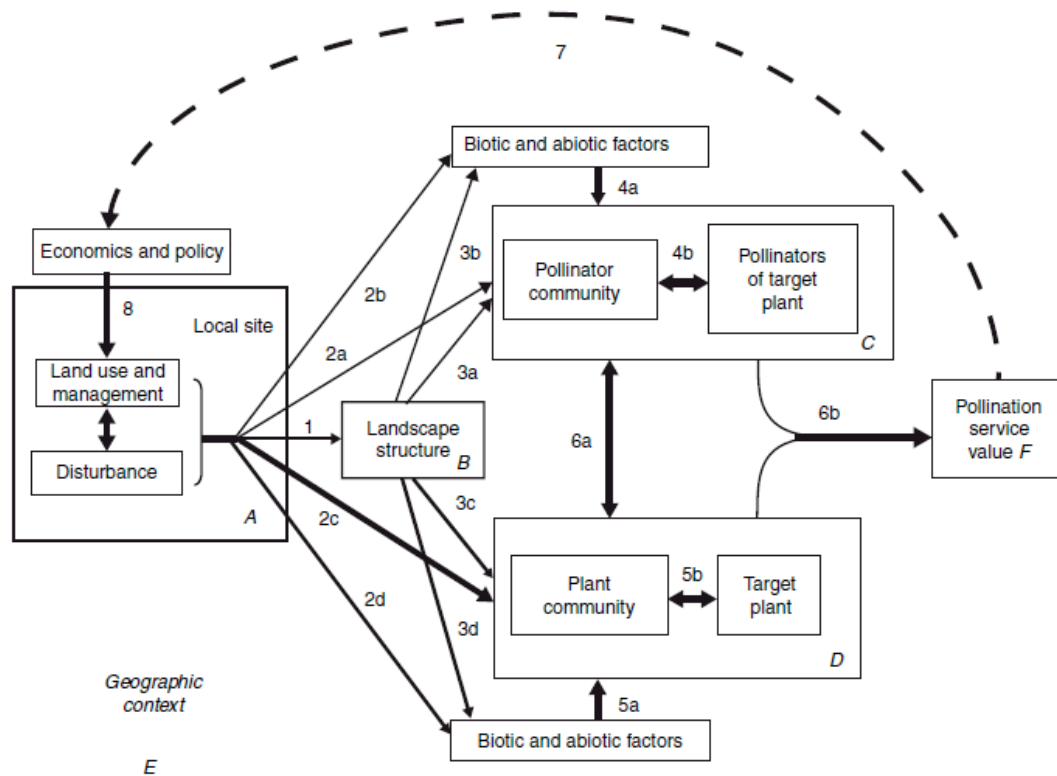
However, recent public discourse supports conservation of biodiversity in agriculture. A growing number of concerns about the effects of agriculture on biodiversity from the general public are apparent (Van Donkersgoed, 2005). Articles such as “We need to pay farmers... to protect nature” by Webb (2009) in the Toronto Star indicate growing support for environmental stewardship and ecological farming models, and recognize the ALUS pilot project as novel public approach to address concerns.

Environmental outputs, which distill the impacts and/or benefits resulting from implementing PES are important for both agricultural and conservation priorities and policy. The conservation of biological diversity in agriculture is of international attention, and encompassed by ALUS’ attempt to provide wildlife enhancement ecosystem services by restoring or conserving portions of private land as natural cover. Biodiversity in general provides a multitude of ecological, social and economic services. Pollinators and pollination services are one of many possible indicators of the benefits arising from biodiversity conservation in agriculture.

Pollinators and pollination services provide both ecological and economic benefits, and are implicated in academic and public discourse as an important facet of biological diversity to conserve in both natural and agricultural systems. Wild and native pollinators are proven to be effective pollinators on increasing accounts for many crops (Klein et al., 2007; Winfree, Gross & Kremen, 2011). However, their ability depends on adequate abundance and richness. As mentioned, native bees are more efficient than honey bees on a per flower basis for many plants, and with sufficient abundance and richness are as efficient as honey bees on mass flowering crops (Rader et al., 2009). Increased abundance of wild bees has been found to increase production in canola (Morandin & Winston, 2006), watermelon (Kremen, Williams, & Thorp, 2002), and coffee (Ricketts, 2004) crops. Morandin and Winston (2006) find that successful

crop pollination by wild bees is also positively correlated with the amount of surrounding natural land. Properly managed, wild and native pollinators in agriculture may be an alternative to managed pollination systems and may provide insurance against predicted pollination shortages (Winfree, Gross & Kremen, 2011). However, the potential and realized value of this service is still debated and often underestimated.

Few studies attempt to quantify the value that wild pollinators provide in agriculture. Those which do often estimate the cost of an alternative technology or organism to achieve the same function (Winfree, Gross & Kremen, 2011). Other valuation studies of pollination services estimate the crop yield that would be lost if loss of pollinators occurred, which can be quantified and compared for honey bees and wild pollinators if the percentage of pollination performed by each group is known (Winfree et al., 2007). Winfree, Gross & Kremen, (2011) estimate the annual value for wild pollination of watermelon in New Jersey to be \$2.25 million US per year using this method. Gallai et al. (2009) estimate the global value of pollination services to be \$200 billion per annum by calculating the international net worth of crops dependent on pollination; and note that nuts, fruits, vegetables and edible oil crops are the most vulnerable to the loss of pollination services. Lonsdorf et al. (2009) illustrate a conceptual model which describes the provision of pollination services in an agricultural landscape, and the complexity of delivering and quantifying this ecological service (Figure 7).



**Figure 7: General conceptual model describing pollination services and their delivery across an agricultural landscape (Lonsdorf et al., 2009).**

Quantifying the benefits of wild pollinators is difficult. The potential for providing wild insect pollination services may depend on the perception of its value by farmers and the general public (Sanford, 2011). Much of the public discourse about the ALUS pilot project represents pollination services as an appropriate target, or a potential/ realized benefit of the initiative. For example, in an article of the Toronto Star which highlights the plight of native bees, farmers Bryan and Cathy Gilvesy qualify one aspect of their ALUS project as an attempt to restore populations of pollinators (Smith, 2007). More recently, the Norfolk ALUS website posted a YouTube video explaining the well-received uptake of “pollinator hedgerow” projects on farms in Norfolk County (ALUS, 2010). This demonstrates that farmers and administrators of the ALUS pilot project may accept conservation norms about wild pollinators, and elucidates public knowledge of the ecological and economic benefits of these organisms.

## **Conclusions**

Pollinators are an indicator for the Wildlife Enhancement environmental services that ALUS projects seek to provide. ALUS projects on farms in Norfolk County have modified the pollinator community composition present in the landscape, potentially resulting in increased pollination services for both wild and agricultural plants. The abundance and richness of pollinators helps to ensure continued population abundance and richness of wild and cultivated flowering plants, and more stable biological communities overall.

In the future, pollination studies should occur to determine the relative importance of bee and fly pollinators for agricultural crops on ALUS farms. As well, differences in yield could be measured between farms participating in ALUS and non-participating farms to determine if abundance and richness of wild bee and fly pollinators affects pollination success of crops and to what extent. Other indicators of wildlife enhancement services on ALUS farms could provide insight into other beneficial mechanisms of biodiversity, such as the abundance of natural biological control organisms including parasitoid and predacious insects; the presence and diversity of beneficial soil organisms; and populations over time of rare and threatened species in the area.

The ALUS pilot project in Norfolk County provides an opportunity to assess the strengths and weaknesses of this PES initiative before implementing a similar policy on a larger scale. Some aspects of the program should be questioned, including the sources of long-term funding; the possibility of other payment regimes; creating a market for agricultural goods produced by environmental service provisioning farms; and the importance of a priori conservation values in a community. With staggered introduction into other counties in Ontario, ALUS could manipulate variables of program development and desired outputs to target local

ideals and circumstances, and determine the effects of such on farmer uptake and community engagement.

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