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# Conserving Farm Land with Cover Crops and the Importance of Biodiversity

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**Nuffield Canada Agricultural Scholarships**

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2. Stand back from their day-to-day occupation and study a topic of real interest
3. Achieve personal development through travel and study
4. Deliver long-term benefits to Canadian farmers and growers, and to the industry as a whole

**Applications are due annually by April 30th**

# TABLE OF CONTENTS

## Contents

## SCHOLAR PROFILE

I am a fifth generation farmer from Merlin, Ontario, Canada. Working with my father, Elwin Vince and my uncle, Tom Vince, we currently produce commercial corn, soybeans and winter wheat on 1300 acres (526ha). Our farm management practices are centered on soil health. We are considered to be no-till pioneers in our corner of Canada. We adapted to no-till farming techniques in the early 1980's. This was prior to John Deere entering the no-till marketplace with their single disk opener. I am very fortunate to have been taught, from a young age, the merits of no-till farming. My claim to fame, as a 42 year old farmer, is that I have never used a moldboard plough.

Our objective is to leave the soil we manage in better condition for future generations. This is true, regardless if our farm will be owned by my children or someone else's children. I am of the opinion that soil is not an infinite resource.

Today, in my corner of Southwestern Ontario, which is surrounded by the Great Lakes, we are witnessing a reversion away from no-till back towards conventional tillage. This has seen increased pressure on adjacent water bodies with nutrient loading due to soil erosion.

With the use of satellite imagery, it is easy to see the runoff impact from farm fields in Southwestern Ontario. This concerns me greatly since my family derives our drinking water from Lake Erie.

Ongoing tillage practices are contributing to the annual recurrence of blue/green algae blooms in Lake Erie.

This was my motivating factor in applying for the Nuffield Scholarship, through which I have been building on my knowledge and use of cover crops.

# ACKNOWLEDGEMENTS

I am very grateful to my wife Karen for her support, patience and cheerleading.

She has continued to keep the home fires burning, working full time and attending to the demands of our two children, Cora and Elliott. I hope that my children will appreciate one day that it is always important to want to learn.

Thanks to my parents, Elwin and Linda Vince, and my in-laws, Tony and Mary Smeenk, for providing assistance to my wife and children while I was gallivanting around the globe.

I would like to thank everyone who hosted me in their homes and provided a comfortable bed, warm meals and stimulating conversations.

For fear of missing someone that has provided support and answered questions along the path of my journey, I extend a blanket thank you!

To the boys on the bus: Hilly, Joe, Trent, Ed, Tafi, Itzy, Searly, Greenie and Lachie. Thank you to these fine gentlemen for sharing their collective passion for agriculture, the one profession on the planet that everyone needs on a daily basis. Thank you for helping to teach me to “be a passenger."

Lastly, I will be forever indebted to Sarah Singla, a Nuffield scholar from France. We met after a chance encounter at the National No-tillage Convention in St. Louis Missouri. It was Sarah who simply encouraged me to apply. She said,” You know and I know, if you don't apply you will never be chosen." Thank you for seeing my potential and helping me in my incredible life changing opportunity of becoming a Nuffield scholar.

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Those who wish to remain anonymous

# EXECUTIVE SUMMARY


"Our soils are naked, hungry, thirsty and running a fever." Ray Archuleta, NRCS

My objective in writing this report was to provide a document that could be read, understood and implemented by farmers. It is important to remember that I gleaned the information written in this report during my travels around the globe. I also felt confident to implement practices that I witnessed during my Nuffield journey and apply them on my farm. The result of that experiment is included in my report.

Farmers, with the benefit of good, non-commissioned soil advocates, continue to practice farming methods that emphasize soil health. This is a common denominator around the world.

Today, farmers are motivated by physical yield as the penultimate goal. Farmers need to shift their focus and understand that financial yield should be the objective for economic viability.

Soil needs to be better understood as a collection of living organisms. As 2015 will be the United Nations' "International Year of Soils," soil should be recognized as the most precious resource on our planet.

The report will demonstrate that cover crops can reduce the need for nitrogen fertilizer. With living cover crops we can reduce erosion. Living roots help increase soil biological activity. With a living cover crop, photosynthesis plays a valuable role in capturing solar energy 12 months of the year. Water infiltration and water holding capacity are significantly increased with cover crops.

Healthy water which is necessary for all living things on our planet is directly related to healthy soil.

## DISCLAIMER

This report has been prepared in good faith, but is not intended to be a scientific study or an academic paper. It is a collection of my current thoughts and findings on discussions, research and visits undertaken during my Nuffield Farming Scholarship.

It illustrates my thought process and my quest for improvements to my knowledge base. It is not a manual with step-by-step instructions to implement procedures.

Neither The Nuffield Farming Scholarships Trust, nor my sponsors, nor any other sponsoring body guarantees or warrants the accuracy, reliability, completeness or currency of the information in this publication nor its usefulness in achieving any purpose.

Readers are responsible for assessing the relevance and accuracy of the content of this publication.



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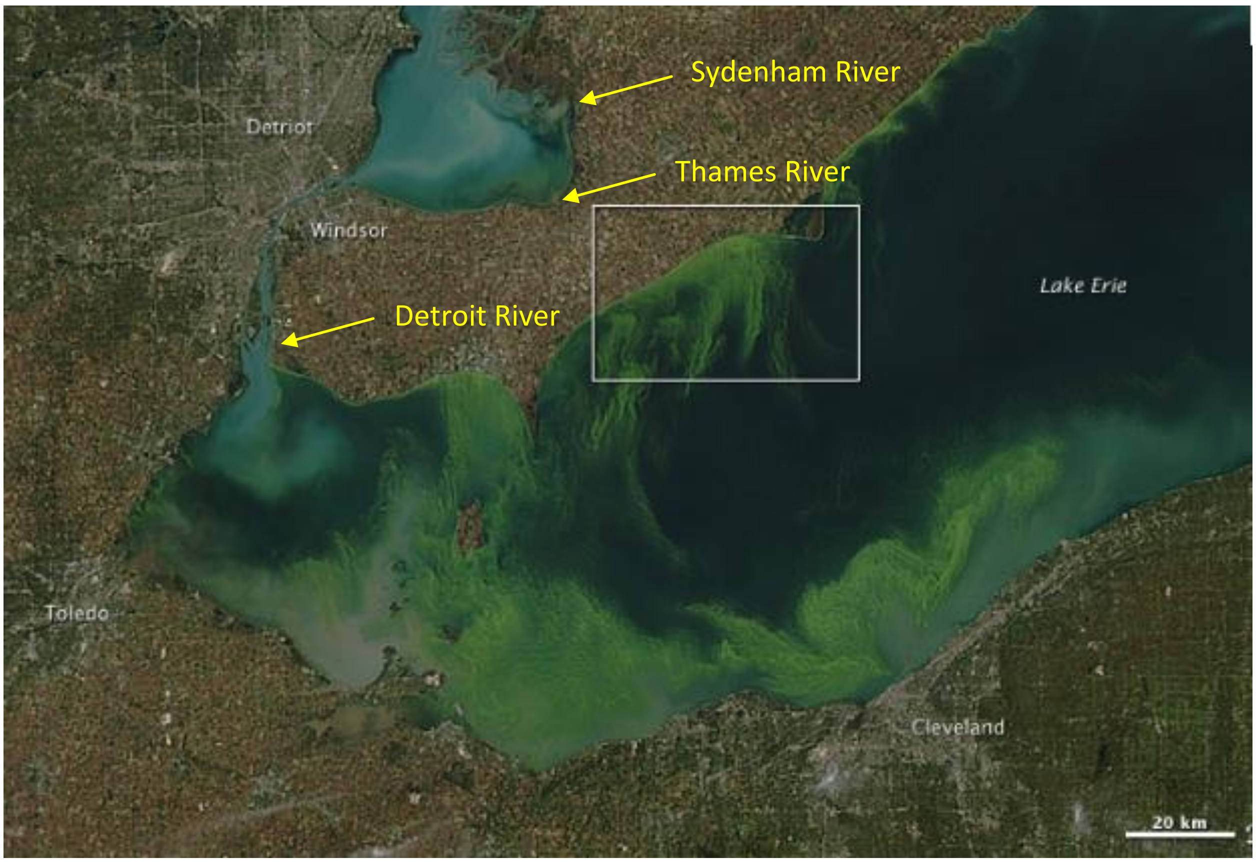
# 1.0 INTRODUCTION

"Those who have the privilege to know have the duty to act." Albert Einstein.

This picture was taken via Satellite on October 9, 2011. It highlights the western basin of Lake Erie and the surrounding areas of Ontario, Michigan and Ohio. This picture was the motivation for my Nuffield study topic.




Source: (NASA Earth Observatory n.d.)

If a picture is worth a thousand words, this is it. The small lake in the top of the photo is Lake St. Clair, a world renowned fishery and a perfect habitat for an array of fresh water fish. This lake is the final destination for two main watersheds in the lower southwest corner of Ontario, Canada.

The photo clearly demonstrates the Thames and Sydenham rivers and the sediment laden outflow emptying into this small lake. The reason the fishery is viewed to be so healthy is that water drains into Lake Erie via the Detroit River very rapidly and is replaced with new water via the St. Clair River, the source of which is Lake Huron.

The agricultural diversity found in this region would rival that of the San Joachim Valley in California.

Where our climate only allows one crop per year and the size and scale of the farms are much smaller than California, it is this unique micro climate provided by the Great Lakes that drives productivity and diversity. Along with the beneficial climate and reliable rain events, the underlying productivity of the soil is the ultimate driver of agricultural diversity.

Corn, soybeans and winter wheat represent the largest percentage of cultivated crops grown on an annual basis. With the recent strength in the commodity market of those respective crops following the American Midwest drought of 2012, many farmers abandoned no-till farming practices and reverted to conventional tillage to maximize yield. This was driven by escalated commodity prices. The thought was that tillage would ensure maximum production.

The no-till movement started across Southwest Ontario in the late 1970's. A group of farmers started a think tank gaining no-till knowledge from farmers in the United States. From this group evolved the Innovative Farmers Association of Ontario. This group is still a leading resource for soil health initiatives in Ontario today.

No-tillage was seen as a viable option and was implemented with success during the early 1980's and continued to see steady growth across Ontario well into the next decade. This was during a period of high interest rates and low commodity prices. No-till helped farmers stay financially viable during those lean years. No-till practices not only had benefits for increased soil health, but it also helped make significant improvement for Lake Erie water quality, which had been deteriorating.

When farmers started to chase physical yield by going back to tillage, the reported increases in yield spread like wild fire. Farmers would also justify their practices with complaints of BT corn stalks being tough to decompose. Soon, the countryside where no-tillage had been gaining popularity started losing traction to conventional tillage.

After multiple years of accumulating surface residue due to no-till, decaying plant material degrades and becomes valuable soil humus. This adds precious organic matter and eventually soil carbon. When No-till soils are tilled, accumulated soil carbon is exhausted as Carbon Dioxide ($CO_2$). It is the carbon flush that gives plants the "yield boost". This yield boost, unfortunately, is short lived following the return to conventional tillage since soil carbon is rapidly depleted. In most cases, what was built after several years of no-tillage, is quickly eroded. After a short term increase in production, yield gains quickly diminish.

When soils are tilled and are void of surface residue, they are vulnerable to wind, water and solar erosion. Soil erosion caused by water carries precious soil off farm fields with phosphorus and nitrogen loading into ditches, rivers and eventually, our lakes. This is a major contributing factor to many water bodies around the globe that are faced with reoccurring algae blooms and hypoxia.

Tillage is an issue causing erosion not only in Ontario - it is seen around the world.

The evidence of man's manipulation of the soil has had such devastating consequences that no amount of remediation will restore soil to the productive value that helps ensure the survival of all living things on this planet.

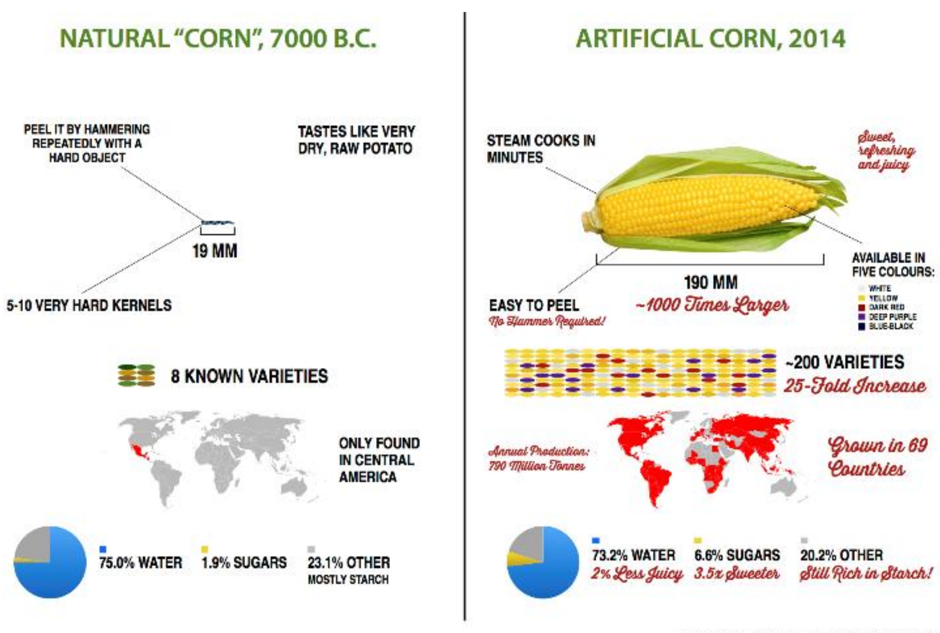
# 2.0 CONSERVING FARM LAND WITH COVER CROPS AND THE IMPORTANCE OF BIO DIVERSITY

## 2.1 BIO-DIVERSITY

Biodiversity by definition: “The variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable.”

The United Nations, in 2010, declared this to be the ‘Decade on Biodiversity.’ In North America, we hear very little mention of this initiative. This is mostly due to the fact that the agricultural landscape, across the largest percentage of arable land in U.S.A., is driven by “King Corn”. In 2013, the U.S. corn production was 87.7 million acres of “yellow gold”. It is hard to argue with the usefulness of the crop that has been in cultivation for over 7000yrs. Today, the crop looks dramatically different than the early versions of corn that more closely resembled grass/grain.

With years of genetic advancement and varietal selection, corn (maize) has become one of the major staples of global grain production.




Source: (Monash n.d.)

It is hard to dispute that corn is not only a truly remarkable crop from a physical production perspective, but the diversity of usefulness is amazing. Today, corn is used as feed for human and livestock consumption. High fructose corn syrup, whiskey and ethanol are all familiar consumables, to name but a few. With the vast array of endless research and financial capital that has been spent fine tuning production systems, it really should come as no surprise that corn has come to be the major crop under cultivation. The net result has significantly increased annual production. Corn has supplanted large tracts of land where alternative crops and plant species dominated the landscape. Today, across large portions of Western Canada, where corn production was not thought to be possible due to a shorter growing season and various weather risks, corn is now under cultivation. Multinational corporations like Monsanto, DuPont, BASF and Syngenta possess underlying seed genetics. These corporations have publically stated that they believe there is potential for an additional million acres of corn to be grown in Canada. As a country that is a net exporter of corn today with approximately 2 million acres of corn produced, the question needs to be asked: "Why do farmers want to produce a crop with numerous increased risks, both physical and financial?"

When driving across the Midwest U.S.A., you will notice an endless sea of corn fields blanketing the landscape. The underlying soil that supports the growing crop could grow an array of different fruits and vegetables. Pastured livestock that once dominated the terrain are found less frequently. Intensively managed livestock operations of pigs, chickens and cattle, fed a diet of corn and soybeans, are housed indoors. The formation of these prairie soils was accomplished by the hooves of millions of migrating buffalo which would graze on native prairie grasses and natural vegetation. This is the famous black earth where it is not uncommon to find top soil that is several meters deep. As a farmer with far less naturally productive soil, I am always amazed that high valued fruit and vegetable crops are not produced there instead of corn.

The reason is quite simple, human labour. In the state of California, 50% of North America's fresh fruits and vegetables are grown. Not only does California have the ability to produce multiple crops during a calendar year, but they have access to a vast supply of low-priced manual labour in neighbouring Mexico. Thousands of annual migrant workers flock to the fields harvesting North America's fresh produce.

In the Midwest, crops such as corn, soybeans, cereals, canola, sunflowers and edible beans are ideal for mechanical harvesting. These crops can also be stored in large volumes and for a long duration with limited risk of storage loss and spoilage.

Today, some vegetable and fruit harvest is done mechanically as well, but many crops are still touched by human hands. The access to a large work force for additional processing of vegetable crops in a highly populated state like California is also a large asset. The highly perishable nature of fresh fruits and vegetables requires another set of management skills and infrastructure. With the ongoing drought that California continues to endure, this has the potential for an enormous impact on the annual output of fruit and vegetables. This drought not only affects people within the state, but has a far reaching impact for millions of people across North America. Today, the farmer struggles with water usage for irrigation to produce a crop, while the urban population wants to have the water for consumption and recreation. The California environmental lobby movement is extremely active and well funded. While visiting California during the spring of 2013, they were aggressively protecting fresh water smelt in a local water course. This was impacting water volumes allocated to farmers producing fresh vegetables, fruit, almonds and large scale dairies, to name but a few of the various elements of California's agricultural sector.

California represents the world's tenth largest economy. Agriculture is a huge component of their economic output. With an ever increasing population and a prolonged drought, water resources for human nourishment continue to take priority over farm irrigation. The need to shift production of vegetables, fruit and dairy to other areas of the continent may need to be considered. It is unrealistic to establish fruit trees and start production in year one. Almond trees would not be well suited in the harsh winter environment of the Midwest. Certain vegetable production systems could be the easiest to establish elsewhere. The limiting factor is the required relocation of processing factories. Shipping produce from the center of the continent to the coast for processing would be too cost prohibitive. Logistically, having a vegetable and fruit production system in the center of the continent would lessen shipping costs for final products heading to market. With the endless supply of feed in the Midwest, dairy production would be a benefit to the local landscape. Fields could be rotated with diverse rotations of perennials and forages. The soil could be rebuilt with animal manure reducing the demand for continual usage of high volumes of synthetic fertilizer, herbicide, insecticide and fungicides

As I write these words, I can already hear the critics screaming about the price of milk, the exorbitant costs of relocation for farmers and supporting processors. I am absolutely aware that profitability by all parties is essential for financial viability. What I do know is that water is the essential ingredient to the equation. The human population needs water for survival. Crops grown in environments like California without irrigation will wither and die. Having an intensely populated state with increasing population growth, coupled with the need for irrigating multiple crops per year has put tremendous pressure on the water resources.

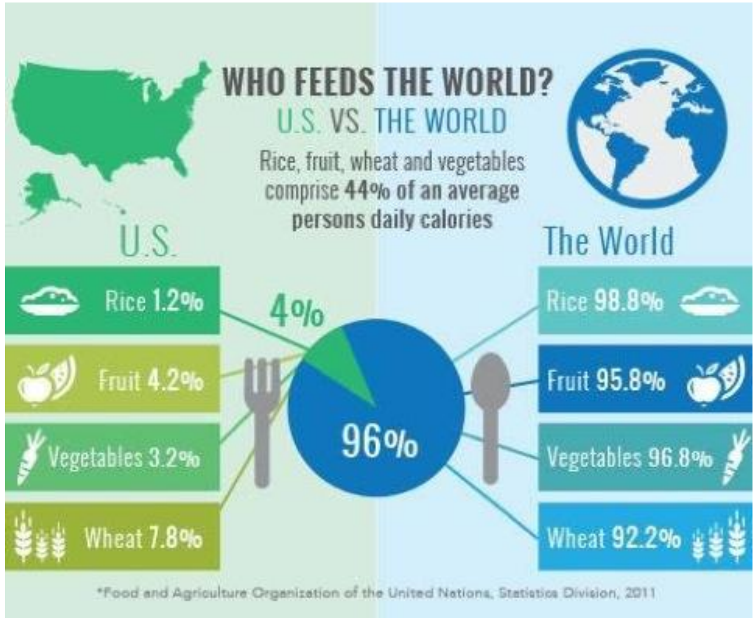
This situation of specific risk where North America has come to rely so heavily on one geographical location is currently very precarious. With a prolonged drought, the magnitude of the situation has even greater significance.

The introduction of crops that can be grown in a rain fed geographic location will lessen the burden on water demand in a drought stricken environment. It will provide economic impetus and strengthen rural economies across North America.

The risk associated with a large percentage of the North American human diet being derived from one location needs to be examined more closely. The time, capital and arable land that has been devoted to corn production needs to come under the microscope. As a farmer I take great pride in producing a crop and watching it grow. I struggle to describe myself as a "producer of food". The corn we grow on our farm is used for ethanol and the soybeans tend to be crushed for oil to be used for bio plastic, bio diesel, soy ink. Aside from the soya meal or the Dried Distillers Grain (DDG's are a byproduct of corn ethanol production) which are used in animal rations, I grow energy crops. Wheat is our only crop that, once ground to flour, is used for numerous foodstuffs. Producers are constantly being reminded of exponential global population growth. Farmers are reminded how we need to grow more food to feed the world. I struggle with this concept as millions of acres of North America produce crops, but not what I would consider "food".

During my last two years of Nuffield studies, I have had the distinct pleasure of hosting many visitors from around the globe. A recurring conversation generally surfaces with every visitor from outside North America who is amazed by the size of North American vehicles. The appetite for gasoline by the consumer does not appear to be lessening in the near future. The priority of food versus fuel is heavily debated. The North American lifestyle is seen by many outside societies as being opulent. Suggesting a reduction of consumption for daily staples of food, fuel and even water are met with strong opposition.

Increasing production to meet increased demand is the basic principle of supply and demand economics. With the global population expanding, simply increasing supply and producing more is not the answer. Today, farm input suppliers keep talking about the year 2050 when the global population is expected to reach 9 billion people. The multinational corporations keep pounding the drum of production, emphasizing the need for North American farmers to increase yield and productivity to feed the world. When you look at the chart below, our role as farmers is better served when food is produced regionally. It is naïve to think that a continent like North America can continue to feed itself and the world as well. We need to teach production systems that make soil management the first priority. Managing soils more carefully will not only increase annual production but will help improve water quality. Cultivating traditional crops which are part of local diets should be given first priority. Cultivation of crops that are not traditionally part of the diet or the landscape continues to diminish the plant species that are cultivated on the planet.




Source: (Food and Agriculture organization of the United Nations n.d.)

## 2.2 THE BENEFITS OF COVER CROPS

### 2.2.i History of Fertilizers/Ammonia

The use of plants to re-energize the soil has been in practice for thousands of years. Some regions refer to it as "green manure". Other geographies use the term “catch crops”. For the balance of this report I will refer to the use of plants to rebuild soil as “cover crops.”

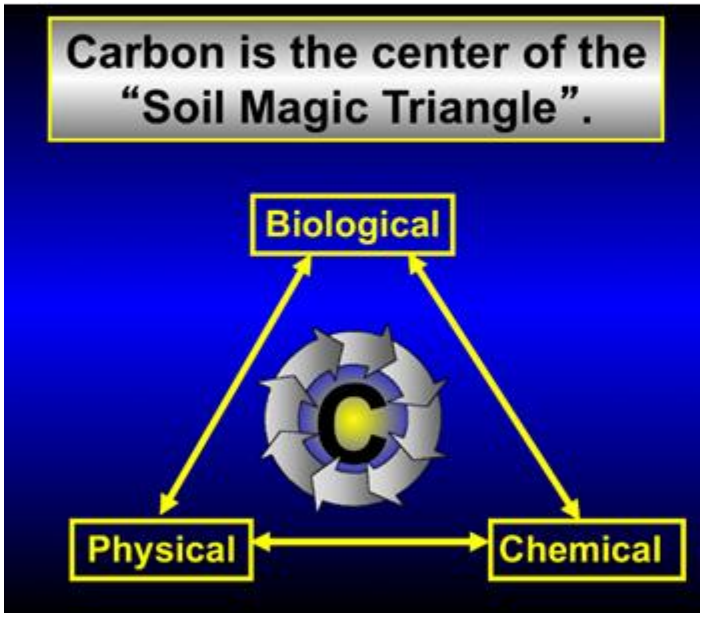
Prior to the global use of synthetic chemical fertilizer, the use of plants to re-energize depleted soils was common practice.

As World War II ended, there were large stockpiles of surplus chemicals used in the production of ammunition. The chemicals, rich in phosphorous, potassium and, most importantly, nitrogen, began being applied to agricultural lands to boost production. The fertilizer industry for today's agriculture was born.

"The Haber-Bosch process, quite possibly the best-known chemical process in the world, captures nitrogen from the air and converts it to ammonia."[1] Ammonia is important because it is the primary ingredient in artificial fertilizers, without which, conventional agriculture yields would be impossible.

This statement is not unlike the thoughts of many agriculturalists found around the globe. Like so many farmers, I have fallen victim to the misleading representation that soil can be corrected or remediated with chemical fertilizer.

[1] (Wikipedia n.d.)




Source: (Managing soil to improve infiltration and water holding capacity: Carbon Management 2013)

We need to reintroduce the biological component of soil management. This is where the value of cover crops plays an important role to protect and stimulate soil biology.

**2.2.ii. Promoting Biological Biodiversity**

Today, most arable land found on this planet is covered with a series of monocultures. Single species are grown to simplify the mechanization process of harvest. Historically, soil cover was never dominated by a single species. When walking across the prairie or walking through a forest or an arid plain, do we find only one plant type dominating the landscape? Year after year, farmers grow an annual monoculture on their fields. A possible exception to this rule would be a pasture or a diversified hay field. Biodiversity's importance rests with the impact that living roots have on the rhizosphere - the area immediately adjacent to living roots. When only one species is grown, specific soil organisms dominate. Living plants produce root exudates which feed living soil organisms. Much like a balanced diet or animal ration, a soil that is covered with increased biological diversity stimulates soil micro and macro fauna. We fail to recognize that there can be as many as a billion bacteria in a teaspoon of healthy soil.[2] We tend to know more details about our celestial system than we know about the soil beneath our feet. Man's quest for life beyond our solar system has taken countless hours of research and endless financial resources around the world. It is ironic that the life in the soil, which is essential for all living things on the planet, receives far less attention.

[2] (Ingham n.d.)

### 2.2.iii. Soil Organic Matter

Long Term No-Till Soils. Carlos Crovetto, Concepción, Chile (Photo by E. Blake Vince)

The Holy Grail of soil management is the ability to increase soil organic matter ("SOM"). This issue has been debated and contested by various authorities around the world. I have had the distinct pleasure of visiting with Carlos Crovetto. He is a no-till pioneer, advocate, teacher and author from Concepción, Chile. During the California gold rush of 1848-1855, wheat was exported from Chile via the Pacific Ocean to feed the demand of the gold miners. At that time, the soil was tilled extensively, with the slope, causing massive soil erosion. Today, over 160 year later, the scars that are left on the landscape are evidence of man's mismanagement with invasive tillage. On most of that land, the only thing growing now are eucalyptus and Monterey pine trees. Carlos' farm is one of the few remaining farms still producing grain. Large ravines, that only support the growth of trees on Carlos' farm, are vivid reminders of the potential for catastrophic consequences due to aggressive, unnecessary, tillage.

In his book "No Tillage," Carlos shares with his readers how he has increased SOM in the top 5 cm by 5% after 42 years of no-till. What is even more amazing is that, at a depth of 10-20 cm, he has increased SOM by 1.76%.[3]

[3] (Crovetto 2006)

| Condition of soil organic matter levels (SOM) and cation exchange capacity (CEC) in Chequen soil after 42 years of no-tillage.[4] | | | |
|---|---|---|---|
| Management | Depth (cm) | OM % | CEC meq/100g |
| 1959<br>Beginning of No-tillage in pastures | 0-5<br>5-10<br>10-20 | 1.42<br>1.24<br>1.00 | 11.00<br>11.00<br>11.00 |
| 1978<br>Beginning of No-tillage in grains | 0-5<br>5-10<br>10-20 | 4.56<br>1.92<br>1.14 | 16.00<br>10.00<br>10.00 |
| 2001<br>After 23 years No-tillage | 0-5<br>5-10<br>10-20 | 6.53<br>2.14<br>2.76 | 23.20<br>18.80<br>18.50 |

*Chequen is the name of Carlos Crovetto's farm

SOM is an accumulation of plant material at various stages of decomposition over a period of time. SOM is host to hundreds of millions of micro organisms, tens of thousands of different species. The accumulation of surface residues both living and decaying, provide an ideal habitat for various species of worms and soil organisms.

Crop root taking advantage of earthworm macropore. (Photo by E. Blake Vince)

Increased SOM more readily absorbs water, releasing it slowly to minimize the impacts of short-term drought. Certain types of SOM can enhance soil water-holding capacity by up to 20 times its weight in water. Studies have shown that for each 1% increase in SOM, the available water-holding capacity increased by 3.7% of the soil volume. For all soil textures, as SOM content

4 (Crovetto 2006),119.

increased from 0.5 to 3%, available water capacity of the soil more than doubled. The combined benefits of increased water holding capacity and increased infiltration with higher organic matter and decreased evaporation with crop residues left on the soil surface all contribute to improve water-use efficiency.[5]

Soils higher in SOM are generally considered to be higher yielding. This may be because SOM acts as a bank account for nutrients. SOM helps to cycle nutrients and increase nutrient efficiency. Tillage of soil tends to destroy accumulated SOM by burning off soil carbon. This release of $C0_2$ with tillage is having a tremendous contribution to greenhouse gas emissions. $C0_2$ is responsible for 50% of global greenhouse gas.[6] With the use of no-tillage and living green plants, farmers could increase SOM with photosynthesis and living roots. This methodology of crop production could be a net benefit for $C0_2$ emissions and has the potential to reduce soil carbon losses.

1 part of carbon =1.72 parts of soil organic matter =3.52 parts of $C0_2$.[7]

This means that with every part of organic matter we leave in the ground we will be rescuing 2.04 parts of $CO_2$.[8]

[5] (Reicosky 2005), 24.
[6] (Crovetto 2006), 126.
[7] (Crovetto 2006), 128.
[8] (Crovetto 2006), 128.

The above photo was taken on Frédéric Thomas' farm, France. Using cover crops and compost, Frédéric has been able to change colour and texture of his sand based soil. The darker colour indicates higher levels of organic matter and soil carbon. Earthworms have been able to extract clay found at 4 foot depth and re-disperse clay with sand topsoil. The soil sample on the right isconventionally tilled by his neighbour and the natural colour of the soil found in this region. (Photo by E. Blake Vince)

### 2.2.iv. Power of Photosynthesis

The goal in annual crop production is to have fields covered with green living plants for the majority of the year. In a perfect world, farmers would have 100% of the soil covered 100% of the time. We need to harness the energy of the sun to produce photosynthesis to extract $C0_2$ from the atmosphere and in return put carbon back into the soil.

Dr. Christine Jones from Australia refers to this as the liquid carbon pathway. The roots of living plants form symbiotic relationships with beneficial soil fungi. These fungi bring nutrients and water to the plant in exchange for carbon. While visiting Carlos Crovetto in Chile, he described carbon as the food of the soil.

The analogy I like to use is: when we house cattle in a feedlot or put pigs in a pen, we know that it is necessary to provide feed. We need to think in terms that soil organisms are our "livestock" and we need to ensure that there is sufficient food to sustain and build the populations in the soil.

In our area, winter wheat plants die off in June and harvest starts in the middle of July. If soil is left bare post harvest, it would be approximately 11 months without a living root in the soil. In this scenario, the field is a virtual desert with very little food to sustain soil populations. When farmers use cover crops to capture the energy of the sun and feed soil organisms, the soil teams with life. Cover crops help to keep soil covered and moderate temperatures. Green cover crops keep soil cool during intense summer months and keep soil warmer during winter. Cover crops create a microclimate underneath the canopy of the growing biomass. Soil temperatures in summer are much cooler with a mulch of decaying organic material. Soil temperatures are warmer during winter months as plant materials act as a layer of insulation. During winter months, when temperatures are well below freezing, it has been assumed by farmers and experts alike that the soil is in a state of dormancy. Research from Sweden suggests that, at -39 degrees Celsius, soil biology is still active.[9] When it is not comfortable for man or beast, there are living, functioning soil organisms.

[9] (NS Panikov n.d.)

11 species cover crop on my farm, Fall 2013. (Photo by E. Blake Vince)

### *2.2.v.* **Erosion**

"The root cause is conventional tillage." Rolf Derpsch

Rolf Derpsch is a no tillage advocate, his work in South American countries of Brazil and Paraguay are well referenced. Rolf is a no tillage pioneer and was instrumental in his role of extension for many countries not only in South America, but around the world. Rolf has written and provided input for many scientific papers regarding no till and improved soil stewardship. Rolf has spoken around the world regarding no tillage and protecting soil resources.

The ability for plants to prevent wind, water and solar erosion should be a sufficient net benefit that all farm land would be covered on an annual basis. Unfortunately, this is not the standard practice implemented on farm fields.

When travelling across Argentina, I was made aware of the 3 distinct soil zones. On the west side of Argentina are the Andes Mountains. The soil parent material was this mountain rock that has blown to the east. Next to the mountains is a region of sand which is larger and heavier by weight. In the middle of the country are the silt loams. The far east of the country is the clay, the smallest and lightest particles that have blown farthest from the parent material.

Living on a heavy clay farm in Southwestern, Ontario the coffee shop critics laughed when I said I was planting a cover crop. They stated with great conviction that," This clay doesn't blow!" My response is "Have you seen brown snow?" The human eye cannot see individual clay particles without the assistance of a microscope. Sand particles being heavier and larger can easily be seen with the naked eye. Great plumes of clay dust rise into the sky behind tillage tools which carry SOM and precious top soil. The process of tillage destroys macropores, micropores and glomalin, the “soil glue” that helps bind soil particles together and provides soil structure.

Water erosion tends to be the most easily recognized form of erosion to the human eye. When fields are tilled bare and void of residue, rain events can have detrimental effects with surface erosion. Crop residue acts like armour protecting soil. Rain events can create surface compaction “crusting”, severely inhibiting seedlings from uniform emergence. Rain events with larger volumes of water can wash soil off the field carrying away precious soil resources in the wash water. Some experts suggest that the impact of rain drops on bare soil has a greater detrimental impact than surface runoff or erosion. Meyer and Mannering (1967) reported that, in one year, raindrops can cause the same compaction to an acre of land as 20 tons of TNT.

Sheet erosion on conventionally tilled soil. Surface soil is exposed. When subsoil is frozen and a rapid thaw occurs with a rain event, surface soils become saturated and release, carrying topsoil and nutrients into adjacent water sheds. (Photo by E. Blake Vince)

### 2.2.vi. Infiltration

Using roots to open soil channels and provide aeration is one of the many attributes of cover crops. The roots of cover crops help penetrate the compacted region of the soil profile known as the “plough pan”. This restrictive soil layer is generally located 6-12” below the soil surface and is created as a direct result of tillage. Consolidated soil is very limiting to root development. This is a barrier which prevents the roots of crops from entering deep into the soil profile extracting precious water and nutrients. During rain events the plough pan can severely limit water from recharging soil at depth since water is unable to penetrate this barrier. American soil health advocate, Ray Archuleta (NRCS) states: “farmers don’t have a soil runoff problem they have a soil infiltration problem.”

Living roots provide an ideal environment for micro flora and fauna to colonize and feed off root exudates. As the top of the plant dies, the root starts to decay. This provides a channel, when left undisturbed, for water to percolate down into the soil profile. The Double Ring infiltration test is a tool that is used to measure the volume of water that can enter into the soil before runoff occurs. Gabe Brown from North Dakota is utilizing mixed species cover crops with high density “mob grazing”. The Brown family has been able to increase their Soil Organic Matter and significantly reduce the need for chemical fertilizer and herbicide inputs. In 2011, local NRCS agents used a Double Ring test at Brown’s ranch to measure water infiltration. Gabe’s soil was measured with an infiltration rate of 8 inches (203.2mm) in one hour. This is an awesome achievement which many agriculture professionals have difficulty comprehending since conventionally tilled soils would be doing well to handle a one to two inch rain event with no loss.

If we could make soils more resilient to major rain events we could significantly reduce soil sediment, leaving fields and entering adjacent water sheds. I am convinced that modest improvements to soil infiltration could have significant contributions to improving water quality in many at risk areas around the globe.

Cereal Rye – Spring 2014 on my farm. Living roots provide excellent soil tilth and water infiltration. (Photo by Karen Vince)

### 2.2.vii. Growing Nitrogen and Reducing Fertilizer Inputs

The reluctant nature of most farmers when discussing cover crops is not uncommon. The perception is that the cost to implement cover crops has a minimal perceived return on investment. Living in a world where we want instantaneous results from our purchases, cover crop benefits can sometimes take multiple years before changes start to occur. Legumes have the ability to fix nitrogen from the atmosphere with nodules. Nodules are formed on the roots where they are naturally inoculated with bacteria known as rhizobium. The fastest return on cover crop investment is, generally, via legumes. This is especially true if the following crop is a high nitrogen demanding crop, like corn. The ability to reduce nitrogen fertilizer purchases provides immediate return on investment to help defray the establishment cost of the cover crop. New technologies such as the Trimble GreenSeeker handheld crop sensor, which measures chlorophyll in corn leaves with near red and infrared light, is a tool that could be used to determine if additional nitrogen is required. These would be areas of the field that the legumes were not able to produce sufficient nitrogen to match the demand of the growing crop. Organic grain corn producers use legumes like hairy vetch to adequately provide enough nitrogen to their crop.

Well nodulated Faba beans fixing atmospheric nitrogen with rhizobium. (Photo by E. Blake Vince)

After years of applying phosphorus fertilizer to soil, "soil reserves" are locked or tied up. Phosphorus fertilizer is tightly held by clay particles making it unavailable for crop utilization. Buckwheat can be used effectively to unlock bound phosphorus and make it available for plant uptake. Buckwheat is a highly efficient scavenger of phosphorus available in the soil. This is possible with the symbiotic relationship with mycorrhizal fungi. The fungal hyphae bring phosphorus back to the plant in exchange for carbon. If the buckwheat is terminated prior to seed set, it will release the phosphorus that has been extracted. It will be present in the soil for the next crop in rotation.

The benefits of utilizing sunflowers in a cover crop blend are numerous. The sunflower has a deep tap root that can break up compaction while extracting zinc. Zinc is a critical micronutrient for photosynthesis. Zinc is the third most critical nutritional factor affecting grain yield after nitrogen and phosphorus. Sunflowers not only attract pollinators, but also the attention of the neighbours wondering if I'm now cultivating flowers. They also make a beautiful bouquet!

When we look at the potential to reduce expenditures of fertilizer inputs, the return on investment is immediate.

The ability for living green plants to capture solar energy via photosynthesis and capture $CO_2$ from the atmosphere might be the most underappreciated benefit of cover crops. Through this process, the plant deposits carbon into the soil. Carbon is the food source for mycorrhizae fungi. The symbiotic relationship between the plant and the root associated fungus is critical to the development of the plant. The fine strands of fungal hyphae help to extend the surface area of the host plant. This allows for increased nutrient, mineral and water uptake by the host. Many cover crop species such as oats, flax and cereal rye can act as a living host for the development of mycorrhizae. According to Graeme Sait who is a world leader in biological agriculture, "There are only 10% mycorrhizae fungi remaining in soil."[10]

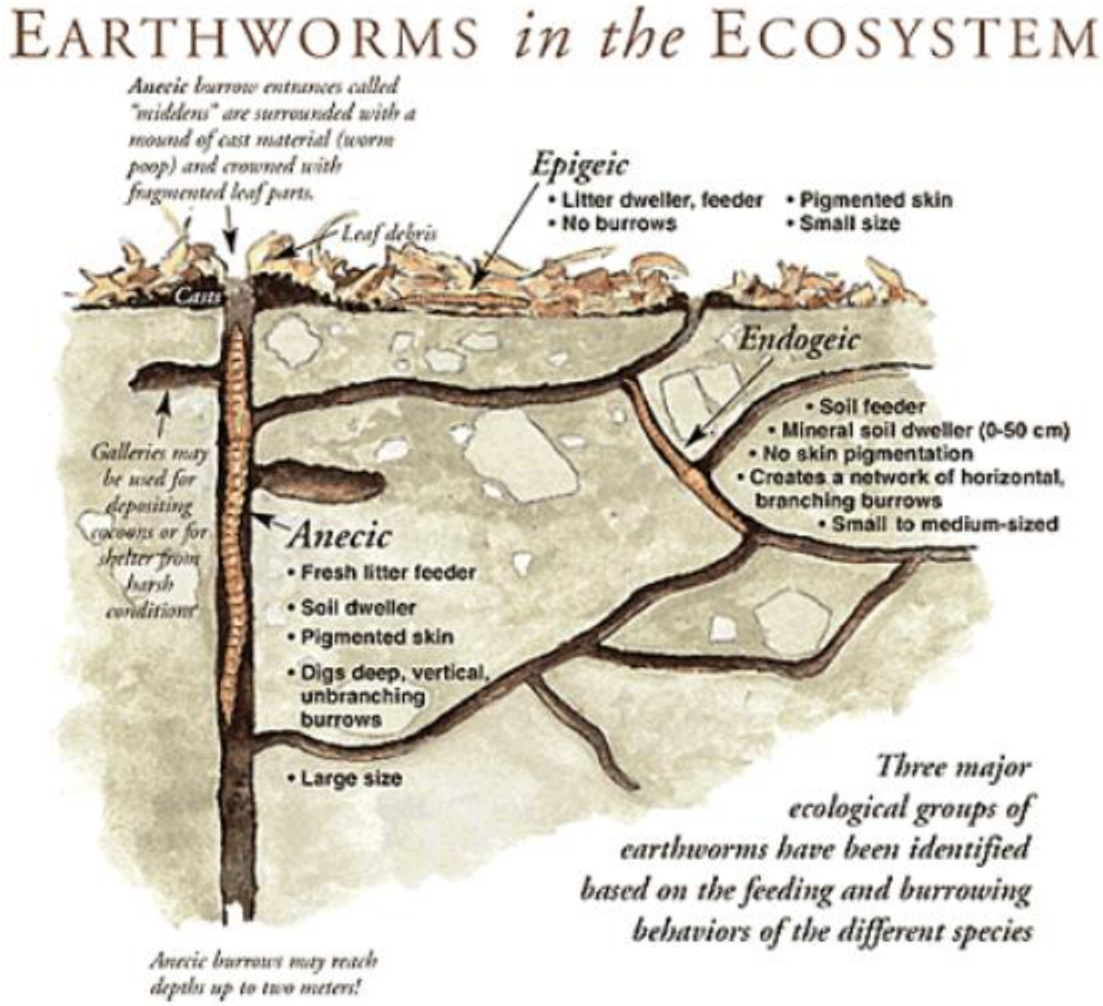
Farmers need to work toward a fungal dominant soil and away from a bacterial dominant soil. Synthetic fertilizers are detrimental to fungal populations. This is caused, in part, by the high salt index of manufactured fertilizer but also by increasing bacterial populations. Nitrogen based fertilizer tends to make bacteria populations explode which consume humus as a food source. Soils rich in humus help drive productivity and profitability. The nutritional value of food increases when grown on humus rich soil. "Above all, humus serves as a carbon filter for our drinking water filtering heavy metals and other pollutants."[11]

### 2.2.viii. Beneficial Habitat

"The more I learn the less I know", is a phrase I heard numerous times during my travels. The direction of agriculture has been driven by production models whose primary focus is yield and increased production for profit. We have lost the focus of healthy soil being paramount to

[10] (Sait n.d.)
[11] (Sait n.d.)

productivity. Sacrificing soil flora and fauna have been viewed as a cost of doing business. As producers, we have lost sight of the importance of beneficial soil organisms and the vital role they play in the soil ecosystem. One key indicator of healthy soil is earthworm populations. Many individuals fail to recognize that there are a multitude of different species that live in the soil. Some are litter dwellers living on the surface under decaying plant material. Some live deep in the soil and make vertical burrows or channels to the surface. Other species live in the soil and never make it to the surface. Worms are only the tip of the iceberg when talking about soil creatures.




Source: (Ecosystem Services, Worms n.d.)

In a healthy soil there are billions of beneficial organisms who are eating, fighting, breeding, working, breathing, living and dying. Therefore, it only emphasizes the importance of having living plants growing for the entire year. The root exudates (sugars) that are released by living roots are the food for the soil biota. The insects that seek refuge in the protected habitat provided by cover crops work to decompose residue and eat weed seeds. Some insects, such as carabid beetles and spiders are beneficial predator insects that feed on other insects that attack crops. Flowering cover crops are an ideal food source for beneficial pollinators.

As I write this report, the Ontario Provincial government has restricted the use of neonicotinoid seed treatments by 80%. This has been to the frustration of many producers who have become dependent on this chemistry. Bans have occurred in Europe and research has tied honey bee mortality and colony collapse disorder to this insecticide. I encourage farmers to think that maybe the honey bee is the canary in the coal mine – one of the obvious signs of a problem. We can easily measure domesticated bees in boxes but we do not have an accurate count on beneficial pollinator populations. Unfortunately, pollinators are not the only insect being affected by neonics. Beneficial predator insects like carabid beetles have also been affected. Carabid beetles have a veracious appetite for slugs. While using a pitfall trap in my cover crop field, OMAFRA summer students were able to capture and count beneficial insects. Populations of spiders, millipedes and beetles all were rising prior to planting corn treated with insecticide. Immediately following planting, beetle numbers crashed. Is this coincidental? Dr. Jonathan Lundgren, an insect ecologist and lead Research Entomologist at the USDA-ARS laboratory, has stated the prophylactic use of neonicotinoid seed treatment is having a negative impact on beneficial predator insects. I am not afraid to admit that I have used these "protective tools". The short sighted view of producing annual crops and maximizing the total physical grain production has been our goal. This attitude has come at the expense of various beneficial creatures which until now have been collateral damage. Luckily, when left alone, these organisms work to build soil, protect crops from various pests and pathogens and will provide a much greater return over the long term.

**2.2.iv. Allelopathy and Bio Fumigants**

Organic crop producers have taken full advantage of the use of chemical compounds released from cover crops to control weeds. Allelopathic chemicals are released from cover crops to effectively control germinating weed seedlings. These beneficial, organic compounds are released from decaying plant material and living plant roots. The use of decaying plant material to provide bio mulch helps to shade soil and prevent light from intercepting soil, triggering weed seed germination. The use of plants such as mustard and radish are known to act as bio fumigants. These plants are both from the Brassica genus. They both contain chemical compounds known as glucosinolates. When they decompose they emit a foul, sulphur odour. The uptake of sulphur by the roots is released as the plant dies, naturally fumigating the soil. This has been an effective remedy to help reduce various species of nematodes.

When pearl millet is used in cover crop mixes, it causes certain nematodes lying dormant in the soil to hatch thinking there is a potential food source. Once the nematode realizes that the food source does not exist, the population withers and dies. This helps to reduce populations of potential nematodes that could jeopardize crop production with restricted root development, caused by nematode injury.


Full season decaying cover crop mulch preventing weed seed germination. (Photos by E. Blake Vince)

Cover crops have been used around the world for thousands of years. The practice of combining a multitude of species and planting them as mixture was a concept that captivated my attention. It is extremely difficult to find naturally occurring monocultures, yet, today, monocultures dominate production agriculture fields. This is due to the need to simplify mechanical harvesting. Using a multitude of species, we are able to mimic nature. When we walk through the forest or across the prairie, we will not find a monoculture of plants. The soil rhizosphere depends upon diversity to stimulate all soil life. This mixed species system of promoting diversity has not been practiced to any great extent in Canada.

**2.3 IMPLEMENTATION AND ADOPTION**

In the summer of 2013, post wheat harvest, I decided to put into practice what I had observed during my travel around the world. I used my own farm to plant a multispecies cover crop to see if this system would succeed in our environment. I blended 6 legumes, 3 grasses, daikon radish and sunflowers together in a blend (hairy vetch, soybean, crimson clover, faba bean, sunn hemp, Austrian winter pea, cereal rye, corn, volunteer wheat, Nitro radish and sunflower).

Following winter wheat, most fields are tilled and left bare. When wheat starts senescence, the roots die as well. The root exudates are no longer produced and soil organisms have no food source. Almost 11 months pass before living roots are present in soil to feed soil organisms. The objective is to have a living root in the soil for 12 months of the year. The plants work harmoniously with different rooting depth and shape. The leaves have various shapes and sizes and plants grow to different heights to maximize light interception and capitalize on solar radiation. The plants grow aggressively as each plant’s goal is to produce a viable seed to ensure survival of future generations.
The goal is to have a collection of warm season grasses and broadleaf plants complimented by cool season grasses and broadleaf plants. The diverse collection of species, provide stimulation

to the soil much like a shot of caffeine. The abundant array of above ground and below ground diversity is difficult to describe. The habitat that is created for the microscopic creatures living below the soil surface and the environment above ground attracts many pollinators, butterflies, moths and ground nesting birds. The transformation was easily witnessed by many curious onlookers who stopped in or slowly drove by.

Living in Canada, frost and winter freezing are good tools for managing cover crops. The cold prevents the majority of species sown from reaching physiological maturity. It prevents seeds that could be produced by the cover crop from becoming a weed that would require management in subsequent crops. After the winter, only winter tolerant crops survived. In this particular experiment, those were hairy vetch, cereal rye, crimson clover and volunteer wheat that germinated after last season's harvest.

The green living crop is seen as a tremendous mental barrier by most farmers. Farmers prefer to have their fields tilled bare, void of virtually all surface residue. No-till fields are the exception where the past season's brown decaying residues are commonly found on the soil surface. Living green cover crop has the advantages of continuing to produce nitrogen and sequester carbon. In a wet environment, like spring in southwestern Ontario, cover crops are a great tool for facilitating evapotranspiration. A farmer's first thought is that the cover crop would prevent soil from drying and delay planting. The other perceived risk is that the green cover crop would harbour numerous pests such as slugs, wire worm and cutworm that would attack newly emerging seedlings.

After a delayed spring planting season, the cover crop continued to grow and finally, the day arrived when the planter placed the seed into the soil. It was the moment of truth. The cover crop did not prevent me from planting any later than my neighbour who planted on the same day. Both fields were finally fit. Truthfully, I could have planted 6 weeks earlier, but I elected to wait due to cooler ambient air temperatures. Admittedly farmer pride was at stake and I decided to err on the side of caution and wait for warmer temperatures.

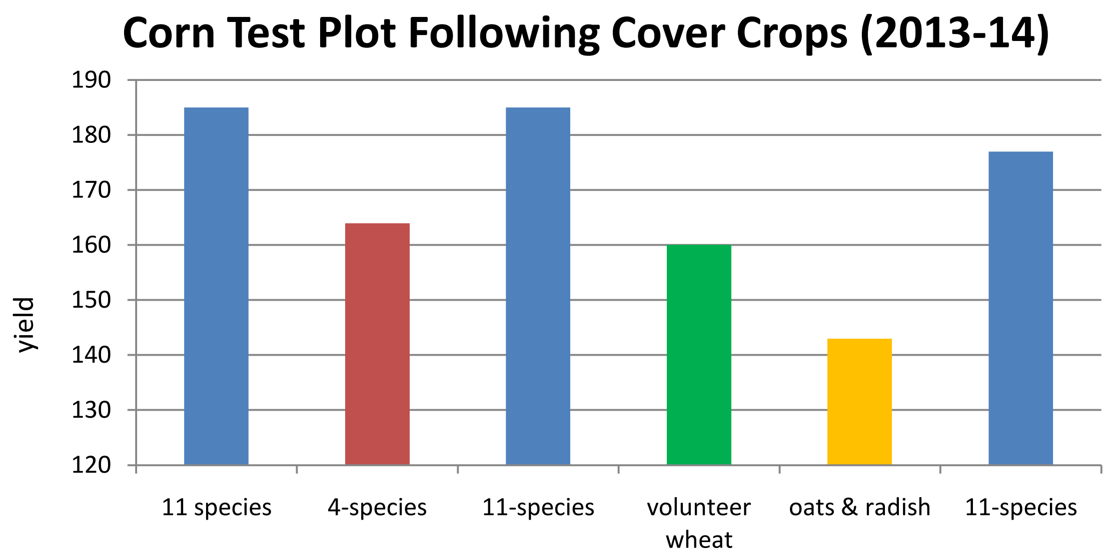
In this profession of agriculture, where the majority of what farmers do is learned behaviour, when someone varies from the traditional practice, it is met with fierce opposition and scrutiny. In my opinion, this behaviour is centred on the fear of change. It is extremely difficult to implement full field scale experiments within the private confines of an office or factory. We do not have tall hedgerows around our property like is common in England. All of my successes or failures are there for the world to see. This experiment made me aware of how many non farmers observe what happens at the farm level as they drive by. Locally, I fielded a greater number of questions from non farmers than I did from farmers. These urban dwellers would compliment me for being willing to protect my soil and would leave with a better understanding of how this ensures healthy water. For myself, it made me aware that consumers are paying attention to where their food is grown. It also validated the role farmers have in society.

We need to continue working towards being seen as good stewards of the soil!

Planting corn into living green cover crop on my farm, Spring 2014. (Photo by E. Blake Vince)

I set up my experiment to compare different types of cover crop mixtures. I used my multispecies mixture as the check and I compared it three times against oats and radish, volunteer wheat and a 4 species winter killed cover crop (oats, radish, cotton and white beans). Each section of the plot was 1 acre. The purpose of the experiment was to evaluate the cover crop mixtures using the same corn hybrid and using a fixed rate of nitrogen. I reduced the volume of nitrogen applied from the former 1:1 ratio (a pound of nitrogen per bushel of corn grown) to a ratio of 0.75:1.

I am pleased to share the results of this experiment with the readers of this report.
I would caution that the outcome of this trial was done in one location, in one year and the results may vary based on growing conditions.




When I planted this plot in the spring I was not sure if the outcome was going to be favourable. To plant into a green cover crop that closely resembled a hay field was far from the norm. This was an environment that most would never consider possible. Long term no till advocate and Nuffield mentor, Jack Rigby, provided some much needed positive reassurance post planting.

During the course of the growing season, this plot attracted over 200 visitors who would all stand between the transition rows across the plot and admire the contrast in colour, height and canopy width of the corn crop. The only difference was the diversity of the previously planted cover crop. They were all amazed at the amount of residue that had disappeared post planting. Visitors would consistently comment on the amount of earthworm casts and middens. More than one person noticed that the soil was softer beneath their feet in the area of the plot with more diversity.

The use of tissue tests to measure nutrient content across the plot provided some interesting data. Where the most diversity existed (11 species cover crop), the tissue test showed a perfect nutrient balance. Where there was less diversity, the nutrients in the tissue test were not as balanced. As the crop matured, this trend continued with grain fill and ear development being far superior in the plots with greater biodiversity.

The progress of the growing crop provided enough confidence that this methodology of planting a multispecies cover crop would be a success. I needed to make the decision to plant the cover crop for the following corn crop without the benefit of seeing the initial experiment through to harvest. I decided to commit our production acres of commercial corn for 2015 to this system by planting a 15 species cover crop.

The transformation that I have witnessed in our soil is amazing. Late this fall, a visitor and I walked across the field with the shovel. We turned over one shovel full of soil and counted an abundant 35 earthworms.

I am very honoured to share what it is I have had the confidence to implement. I attribute a large percentage of this confidence to Nuffield. In the spring of the year the cover crop continued growing aggressively as planting was delayed with several rain events. My father strongly encouraged me to consider baling the cover crop off for hay. I suggested that in removing the crop as hay I would be exporting nutrients that I would later need to replace with commercial fertilizer. If I had my own cattle manure to replace the removed nutrients, that might have been an option, but then I would face the risk of compaction with axle loads of haying and manure handling equipment. I decided to plant the crop directly into the green cover crop as shown in the early photo.

Through this adventure, I needed to remind my critics I was not the inventor of the system. I was simply implementing what I had seen work with success in other geographies around the world.

# 3.0 CONCLUSION

The length of time required to witness improvements to soil can be long and arduous. We need to remind ourselves that soil which is supporting all living things on the planet was created over several millennia. In our world of expecting instantaneous results for our actions, I think this might be the real reason people till. It is obvious that there is a definite cause and effect as soil is turned over, left naked, bare and exposed. During my travels, I have witnessed areas of massive erosion caused by man's excessive tillage exploits. The only way to heal these landscapes will be with time. These soils should be left undisturbed in perennial based plant species. Once established, they could potentially be grazed by large ruminants for short periods of time. I believe this would be the fastest way to recovery.

On our farm, we need to examine our current "crop only" production model. The use of livestock in my farming operation may be the missing ingredient. I believe the way forward will be incorporating perennial forages and grasses, annual crop production under-sown with cover crops. The ability for maximizing productivity by capturing maximum solar energy cannot be done solely with annual crops. Cover crops are witnessing a rebirth around the world. As margins decrease and costs continue to escalate, cover crops will help maintain productivity and profitability.

The benefit of capturing carbon with photosynthesis has never been done and never will be done with tillage.

I would be greatly remiss if I did not take the time to recognize David Brandt from Carroll Ohio, U.S.A. I first met David at a field day in his home state of Ohio. I was there looking at field machinery demonstration. David was there preaching from his "pulpit", the soil pit. He called me over to the side and said these words to me as he pointed at the machine, "I can do way more with roots than you can with that machine". In typical Dave Brandt fashion, he invited a colleague and I to his farm. As we drove across the fields and we looked at his crops and various cover crops, I knew at that moment, I needed to look at the possibilities cover crops could provide to my farming business. A few months later David introduced me to Sarah Singla, a no till farmer and cover crop guru from France. Sarah shared with me her passion for no-till, cover crops and Nuffield.

The proverbial hook was set and I was determined to become a Nuffield scholar.

## 4.0 RECOMMENDATIONS

In our fast paced world of technology and modern conveniences, soil, which has been around since the beginning of time, does not receive much fanfare. Perhaps it is due the belief that it has always been here it will always be here? We have become complacent as it pertains to soil management. We have become addicted to physical and chemical soil remediation tools. Soil needs to be carefully managed. The first priority is to recognize the importance of soil biology.
Cover crops should be standard practice whenever possible! Planting a diversity of plants simultaneously avoiding monocultures by combining a minimum of 4 species
Soil should never be referred to as dirt! Soil is the most important resource on our planet. Soil is a living breathing organism which is essential for every living thing on earth.

As stated earlier, by 2050, we need to be able to feed the expected world population of over 9 billion people. Nowhere have I heard improving soil as the key ingredient to reach this goal.

Soil needs to have living green plants capturing solar energy for 12 months of the year.
With living plants, we can capture $C0_2$ and make our soil the largest carbon sink on the planet.

To all of you that continue to advocate for soil health - thank you! With 2015 being recognized as the year of soil, remain steadfast in your convictions.

If all I have written in this report fails to resonate, I will paraphrase my cover crop mentor, David Brandt, Carroll Ohio...... "Roots Not Iron."

## 5.0 GLOSSARY

**Allelopathy -** the suppression of growth of one plant species by another due to the release of toxic substances

**Biota** – the total collection of organisms in an area

**BT Corn** – Genetically modified corn. A protein, bacillus thuringiensis, was genetically inserted into the plant for the benefit of insect resistance.

**Cation Exchange Capacity** - the number of exchangeable cations per dry weight that a soil is capable of holding, at a given pH value, and available for exchange with the soil water solution. CEC is used as a measure of soil fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination.

**Glomalin** – is a form of stabilized carbon found in the soil. It is a glycoprotein and acts like a glue, that helps give soil structure

**Evapotranspiration -** loss of water from the soil both by evaporation and by transpiration from the plants growing thereon

**Exudate –** organic compounds and enzymes that leak from growing and expanding sections of roots. They help to regulate the fungal community

**Glucosinolate –** sulphur containing chemicals that are a natural component of many pungent plants such as mustard, cabbage, horseradish and brassicas genus of plants.

**Hypha** - one of the threads that make up the mycelium of a fungus, increase by apical growth, and are transversely septate or nonseptate

**Hypoxia** - Being starved of oxygen

**Macropore –** Large soil pores that assist the infiltration of water and air. They provide a beneficial environment for roots to penetrate deep into the soil profile and may provide protective habitats for beneficial soil organisms.

**Micropore** – very small pores which are only accessible by soil fungi and fungal hyphae. They provide a source of nutrients and additional water holding capacity.

**Mycorrhiza** - Product of close association between the branched, tubular filaments (hyphae) of fungus and the roots of higher plants. The association usually enhances the nutrition of both the host plant and the fungal symbiont.

**Neonicotinoid** – a class of insecticide which act as insect neurotoxin. This affects the central nervous system of insects resulting in their death.

**NRCS** – National Resources Conservation Service

**OMAFRA** – Ontario Ministry of Agriculture, Food and Rural Affairs

**Rhizobium** - any of a genus (*Rhizobium*) of small heterotrophic soil bacteria capable of forming symbiotic nodules on the roots of leguminous plants and of there becoming bacteroids that fix atmospheric nitrogen

**Senescence** - the growth phase in a plant or plant part (as a leaf) from full maturity to death

**USDA-ARS** – United States Department of Agriculture – Agricultural Research Service

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