Effects of Off-Highway Vehicles on Soil Environments

By

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Abstract

Rapid growth in off-highway vehicle (OHV) use in North America leads to major concerns about potential impacts on the environment. OHVs are used in a multitude of terrains which allows these vehicles to have many more uses than just a sport because they can get places nothing else can. Impacts of OHV traffic on infiltration rate and soil erosion were evaluated in five driven and non-driven sites located at Cliffs Insane Terrain in Marseille, IL. Though differences were not significant, there was a trend of decreased infiltration rates on the driven areas compared to the non-driven areas. In areas with continuous vehicular traffic, soil erosion and compaction were also moderately, but not significantly, higher. The lack of significant changes in soil structure could be due to good maintenance practices; the Cliffs Insane Terrain has been maintained monthly by soil grading machines, in order to minimize the impact of the environment and to keep the terrain park open to all types of OHV. The increasing number of OHV riders compounded with the problem of decreasing riding areas has caused many agencies to implement such best management practices (BMPs) as the Cliffs Insane Terrain has, which should reduce the amount of soil erosion and sediment loss on trails. These BMPs along with maintenance are potential solutions to minimize the impact because they give guidelines on the proper way to wheel among all types of terrains. This is because the impact is concentrated to managed areas, preventing additional damage from the development of new trails.

Introduction

Four wheeling through mud, snow, sand, and woodsy trails is one of the fastest growing outdoor recreational sports throughout the United States (Sylvester 2009). The off-highway vehicle (OHV) lifestyle includes a variety of users including those who are interested in the pleasure and thrill of operating their vehicles, those who use these as an significant part of an outdoor recreation experience such as sightseeing and wildlife viewing, and those who use the vehicles as transportation for their recreation activities such as hunting, camping, trapping, or photography. OHVs can be especially beneficial for those who have physical limitations (Rooney 2009) because these vehicles allow you to cross terrain in the comfort of a seat. However, four-wheeling is also one of the most destructive outdoor recreational activities due to the heavy weight of the vehicles and modifications that allow the OHV to travel into new areas.

The rapid growth of OHV in North America leads to concerns about potential impacts on soil and wildlife/plant populations. Wheeling is a worldwide sport which consists of vehicles performing on terrain above and beyond the daily roads of a normal vehicle. Being a worldwide sport, has shown many different problems but more specifically in the United States because the sport is being spread quickly. Registrations grew from about 5 million vehicles in 1972 to more than 36 million in 2002. Off-highway vehicle use on most public lands is poorly managed, covering the landscape with a web of motorized paths and roads. The poor management within these landscapes has led to many states limiting use in some areas and creating action plans in order to control the growth of damage in sensitive environments. In highly populated states, public OHV recreation areas are being shut down every year. In California, where population is higher than in any other state, entire sections of the state are shutdown to OHV usage (Bond 2008). The reason is that these areas are generally open access which allows over use to occur. In Colorado, on the other hand, the population is low enough, that there are enough areas to provide enjoyment for all who wish to pursue OHV adventures without the adverse affects (still need to find the reference). Such a rapid growth can allow vehicles to spread invasive species by carrying seeds to other communities which they have not previously grown in, allowing these species to spread in another environment. Invasive species, which are non-native vegetation to the area, have a negative effect on the quality and accessibility of recreational lands available for many recreation activities including Off-highway wheeling. Invasive species are eliminating native plant species, changing wildlife habitats, and modifying the landscape. When left unmanaged, these threats will contribute to a diminished quality of outdoor recreation within the state (Rooney 2009).

In Colorado there is an Adopta-Trail system in which volunteers maintain the trail system they are using eliminating waste, some invasives, and grooming trails. However, even in Colorado, the population is growing at a rate which will not allow for sustained OHV usage in open areas. Management decisions have to be made to ensure that there are few conflicts between OHV users and other users of the available public lands (Bond 2008). Currently there have been some management decisions that have been put into place in the state of Colorado by the Bureau of Land Management defining the specifics of what can and can't be done by OHV users on public land (BLM). Decisions on OHV designations on administered public lands are assigned through the land use planning process. During this process the BLM works together with the public to try to weigh all the competing interests that are being affected by the use of OHV. BLM managed lands are then categorized into 3 broad types of OHV designations - Open, Limited or Closed. The Limited category has several types of limitations depending on which trail it is. The three limitations of use on public land are categorized by the BLM are limited to existing routes, limited to designated routes or limited seasonally (Bureau of Land Management 2010). In order for the BLM to maintain these trails and regulate them, they need to charge registration fees for these OHVs. OHV recreationists in Colorado do not pay any fees except for the registration fees on their vehicles, which is $25 for dirt bikes and ATVs and a minimum of $32.60 for a street-legal 4x4 vehicle, varying depending on the year manufactured and the original cost of the vehicle (USDOT, 2001). The fees generated by registering unlicensed vehicles go into a State OHV Fund that is used to build and maintain riding opportunities in the State. In Montana it was estimated that the OHV community spent about 1 million dollars for registration and licensing of their vehicles with parks and state (Sylvester 2009). OHV users may receive a much higher level of benefits, such as the enjoyment of a hobbyist combined with what nature has to offer. These benefits are not captured in the price of the registration fees and hence are a non-market in nature meaning that there isn't a true price that holds the value of nature (Bond 2008).

There have been many discussions among scientists that off-highway vehicles damage fragile habitats and that much more information is needed before official sanction is given for their continued use over extensive areas (Stebbins 1974). Public lands commonly have designated areas for OHV recreation. Off-highway vehicle use becomes highly concentrated at these sites with a visible influence on the landscape through roads and trails, soil compaction, increased wind and water erosion, and vegetation alteration (Tull 2007). These constant disturbances on the environment caused by OHVs may also give a heightened stress on plant populations at OHV sites which can potentially result in developmental instability of native growth. Ecological impacts on native species from expanding human activities in recreational lands outside areas due to soil disturbance from these vehicles are not as well as observed as other given terrain. It is important for land managers to have ways to detect the stress levels on plant populations that are being impacted by recreational activities due to changes in soil compaction, preferably as an early warning indicator of possible population decline. Much of this activity is still occurring on public land that could possibly link to a change in soil structure, so there has been concern about damage to these areas and invasibility of non native species. This is because native plants to these once non compacted soils are not adapted to what has now become compacted soil environment which is changing due to the weight and constant use of OHVs. Presidential Executive Orders 11644 and 11989 require that agencies in the U.S.A. are to be held responsible for the management and testing of public lands that are being driven on with OHVs, and to adapt policies which protect public resources, including soil. However, with changes in seasonal and temporal use patterns, it allows areas to develop differently between OHV trails and roads/recreational trails.

As stated by Brady and Weil (2010), soils are often defined in terms of factors as complex natural bodies having properties in which are derived from the combine effects of climate and biotic activities, modified by topography acting on parent material over time. This shows that there are many factors in which can contribute to soil being altered and potentially eroded. In a comparison test of soil erosion in areas where OHV usage was very prominent and an area where OHV had been restricted, Snyder et al. (1976) found that due to vegetation damage from these vehicles, the area with prominent OHV usage had eight times greater soil erosion then the control area which had restricted vehicle usage. There are two basic processes of soil formation, transformations and translocations. Transformations occur when the soil composites are chemically/physically altered, while others are synthesized from parent material. Then there are translocations, which are the movements of organic and inorganic materials within the horizon either vertically or laterally. The percolation of water within the soil through capillary action is the main transport for this organic material to spread within the soil. If the soil has become too compacted from the constant use of heavy OHV then there will not be enough organic matter within the soil for plants to receive the sufficient amount of nutrients.

Testing organic matter within a soil sample will show us if there is a significant amount of vegetation present in the soil. Organic matter serves as a reservoir for nutrients and water in the soil helping reduce compaction and increasing water infiltration into the soil, increasing the health of the soil.

Soil tilth refers to the physical condition of the soil relating to plant growth. The tilth of a soil depends not just on structure and stability but also on factors such as bulk density, soil moisture, drainage, infiltration of water, aeration, and capillary action of water. Tilth can change rapidly due to climate change and any biotic factors. A major basis for the tilth of a soil is what is called soil friability. Soils are friable if they are not sticky and crumble easily revealing their aggregates (Brady and Weil 2010). Each soil usually has its own optimum water content for the greatest friability. Clay soils are usually prone to puddling and compaction because of the soil particles high plasticity and cohesion between each other. When clay soils puddle they typically become very dense and hard. This type of soil takes an extremely long time to dry and may also become too dry at times. An increase in soil organic matter content typically enhances friability and could possibly eliminate the susceptibility of a clay soil to structural damage (Brady and Weil 2010).

Soil erosion is one of the main impacts associated with OHV trails (Dotzenko, Papamichos, and Romine 1967). This is caused by the heavy weight of the OHV continuously driving over these trails. The loosening of soil particles on the surface by energy impacting the surface from rain is the primary factor of erosion, particularly on soils with little vegetation coverage which have been continuously compacted by a vehicles weight. "The energy released at the surface during a large storm is sufficient to splash greater than 200 tons of soil into the air on a single hectare of bare and loose soil (Brooks 2003)." Once a soil particle has been loosened from its original position, the runoff will tend to flow towards the point of lowest resistance while accumulating soil particles as it flows. As the runoff begins to collect in small channels, the erosion is characterized as rill erosion. The channels formed by rill erosion concentrate the water into a confined area causing the velocity of flow and turbidity to increase (Brooks 2003). This increase in turbidity increases the rate at which erosion occurs on bare surfaces such as ORV trails. The volume of water moving down the slope is also an important factor of soil erosion.

Soil is a basic resource, the key piece of any form of land use. Soils are very dynamic and will also change as the environment modifies by the intensive recreational use. OHVs when driven near streams can cause damage to riparian vegetation by the degradation of water quality and potentially impacting plant and wildlife habitats (Novotny 2003). Erosion for example can lead to sediment build up within bodies of water, which can cause loss of spawning habitats for species, and also vegetation that require undisturbed stream habitats in order for survival (Novotny 2003). A previous study by Payne et al (1983), recorded that there was a direct relationship between the number of trips over a specific area and the amount of damage to vegetation. After 32 passes with an OHV there was an approximate 99% loss of vegetation on that trail (Payne 1983). The vegetation loss that was measured in the experiment was found to carry over into following years. After one year, up to 85% of the tracks left by the 32 passes from the OHV were still visible. Some tracks were still evident two years after the last passage. Evidence of a degraded riparian area will typically exhibit stream flashing more frequently. Stable riparian environments can stabilize stream banks through bank cover and root masses which are important for fish habitat.

Types of OHV Use

There are many different terrains that these vehicles can travel onto with minimal difficulty which is why this recreational sport can be so destructive to the environment that surrounds it. Each type of OHV use can be linked to a different impact on each specific environment because of the specialized equipment and driving techniques that are tailored for individual vehicles and their drivers.

Dune Bashing, a form of wheeling that is usually found within deserts or sand dunes making it more difficult for the tires to move around within the sand. However, it is less difficult in matters of technique and impact on the wildlife due to minimal amount of obstacles within a dune such as trees or excessive growth of plant species. This type of wheeling has very minimal requirements in terms of modifications, a very light suspensions lift with slightly larger than stock tires are needed to navigate through this terrain. A previous study on the barrier islands by Judd, showed that although infrequent travel over dune vegetation along the coastline by OHV over time caused considerably noticeable and immediate impacts. These impacts have resulted in permanent damage to the vegetation along the coastline of the barrier islands, ultimately caused by repeated travel of vehicles over the same tracks (Judd et al. 1989).

Terrain Wheeling is the most general type of wheeling which is a configured of every other types of wheeling. This is a form of wheeling which can become highly technical due to the landscape that is usually very dense and forested. To wheel in this terrain a spotter can be necessary in order to climb a subtle rise cliff which has several obstacles/uneven rocks that can cause severe damage to the vehicle. A winch, suspension modifications, and larger tires are required for this type of wheeling because there is a diverse terrain including hills, rivers, mud bogs, and boulders. Tree savers are a piece used most often in the wheeling world because when you are winching the vehicle out it needs to be wrapped around a solid tree which can support it allowing severe damage to the growth of the tree. They will also contain a long arm suspension which allows the most articulation in the body in order to successfully maneuver through the multitude of terrains.

The BLM of California (1977) compared dune wheeling and terrain wheeling, which have compared the effects of a full size 4x4 (Ford Bronco) on a desert sand environment. The authors (Adams et al. 1977) sampled the different effects of the Bronco on wet sandy loam soil and on dry sand. Throughout this they measured the impact through multiple passes on the same ground in order to test how wet sand loam and dry sand held up to the compaction from the vehicle. The passes of the Bronco on the wet sandy loam sites produced an increase in soil strength and compaction to a depth of 45cm in which made it very difficult for plant species to survive. However after multiple passes on the dry sand sites, there was very little significant change in which greatly affected the plants living in this environment. The roots were not as limited to extension as they would be in the wet sandy loam. The compaction that was measured on the dry sand sites was less than 20cm in depth therefore still retaining its structure (Adams et al. 1977). There was greater water content in drying compacted soil than in drying non-compacted soil because of reduced plant growth and transpiration on the compacted soil.

Another type of wheeling which is generally suitable for any four wheel drive vehicle, even with factory equipment without the worry of becoming stuck is Greenlaning. This form of wheeling is also generally popular with All Wheel Drive vehicles where off road capabilities are limited. The term “Greenlane” refers to the fact that the routes are predominantly along unpaved tracks, forest tracks, or older roadways that may have fallen into disuse. For a lot of greenlaners, the main emphasis is on enjoying the countryside, and accessing areas that may be seldom traveled by motor vehicles, rather than exploring the performance envelope of their vehicle. These vehicles do not need any modifications and can usually be traveled on with stock suspension and preferably All Terrain (AT) tires that are capable of handling terrains on the road and mild trails

Mudding, a form of wheeling also known as Mud Bogging, which involves finding a large area/pit of wet mud or clay and attempting to drive as far through it as possible without becoming stuck where recovery gear is needed. Traction and momentum are important factors in success to get as far as possible are used for this type of wheeling typically are stripped down trucks with high powered engines or smaller vehicles that has quick acceleration. Mud-terrain tires (MT) are required for this type of wheeling because they have extremely deep grooves which allow the mud to clean out of the tires while they are in motion. Strongly attached recovery points are required as well to enable the vehicle to be towed out if it becomes bogged down.

Rock crawling is a highly technical type of wheeling, which involves a lot of maneuvering and patience by both driver and spotter. Vehicles are typically modified with larger Mud terrain tires which will allow better grip, lifted suspension components allow greater axle articulation of the vehicles body, and changes in the differential gear ratio to provide the high torque/low speed combined with a locker which helps operation for navigating obstacles. The tires will also be aired down to allow more grip, but may cause more environmental impact on the soil around it because the tires tend to dig deeper into the soil kicking up more, allowing it to erode at a faster pace. It is common in rock crawling for the rock crawler to have a spotter - an assistant who will go on foot alongside or in front of the vehicle. This is so the spotter can provide information to the driver on routes, obstacles, or areas of terrain that the driver may be unable to see to successfully finish the trail.

Rock Racing although similar to the very slow and skillful rock crawling, this type of wheeling is not about being articulate and technical in order to get up the hill, it's all about speed. For this type of wheeling, accomplishing the trail as fast as possible without worrying about any penalties for hitting cones, reversing, or winching. The equipment used with this type of racing is going to be very similar to the necessary rock crawling equipment however the type of tires will change. Race cut mud tires are required in order to provide more grip while also maintaining the ability for the tires to clear out any debris caught within the treads.

Winch Wheeling is form of wheeling which can be very destructive if the right equipment is not used. This type of wheeling involves attempting to access areas that would be impassable without the use of a winch. A winch is a motor driven reel attached to a strong steel cable, which can assist in pulling a vehicle from being stuck. The use of a winch would include such areas as deep gullies, steep slopes, highly forested areas with moist conditions/very technical trails. Most off-road vehicles that have been prepared for this type of event will typically have two winches. One located on the winch mount of the front bumper and the other located on a rear winch mount, each with a rated pull of a minimum over 9,000 lbs.

A majority of forestlands across the country have no roads and have not been significantly altered by motorized disturbances. These roadless areas maintain a healthy soil, provide clean water, and act as a refuge for wildlife (USDA 2000b; DellaSala and Strittholt 2002). Roadless areas have remained untouched primarily because they are remote and inaccessible. Today, most remote roadless areas can be accessed in just a few hours on an OHV. The objective of this study is to evaluate the impact of Off-Highway Wheeling on soil environments. If Off-Highway Wheeling continues to maintain itself as one of the fastest growing outdoor recreational activities, it is predicted that there will be a dramatic increase in compaction and soil erosion which can result in a reduced amount of precipitation infiltration and organic matter within the soils of driven terrain.

Methods

Field Sampling

Field studies were initiated in Marseilles, Illinois at a Terrain park, Cliffs Insane Terrain, to compare the soil compaction of driven and non-driven terrain. Cliffs Insane Terrain is a privately owned terrain park which spans approximately 300 acres with about

70% of the land has been wheeled on, and plenty of vegetation and soil which remains untouched by vehicles.

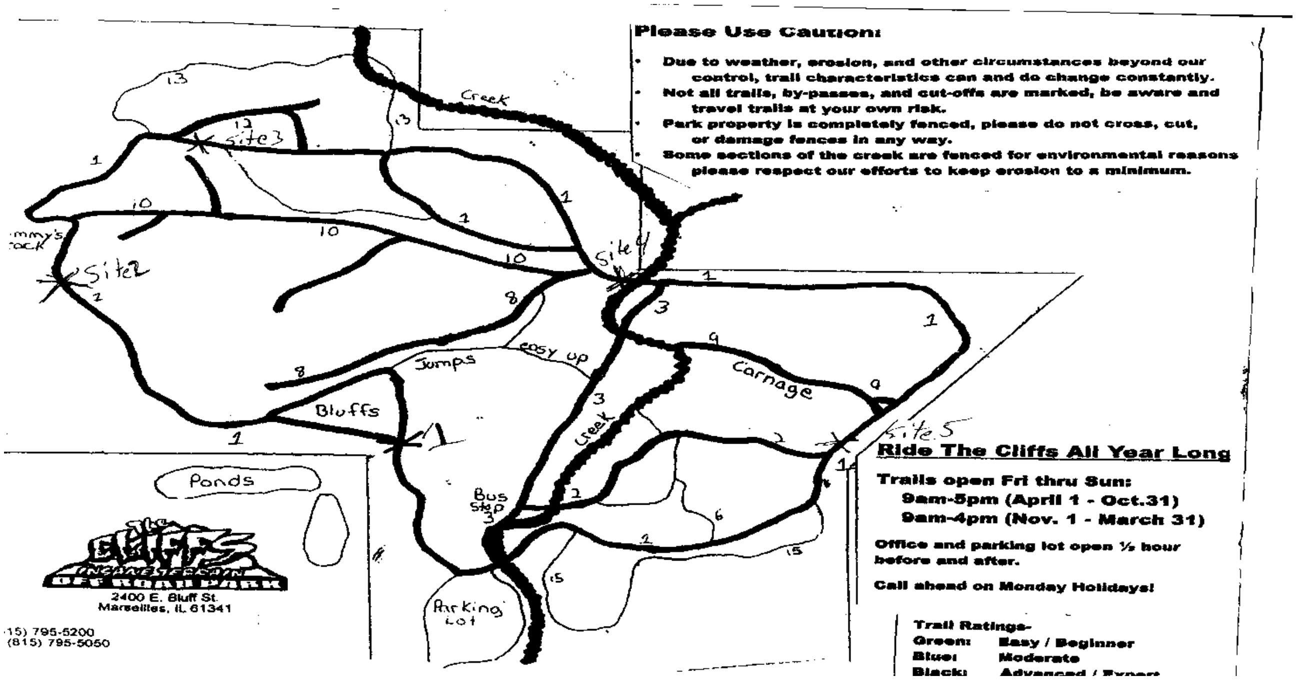

Figure 1: Site map of The Cliffs Insane Terrain with each of the 5 plots marked by an X

Five different areas were sampled throughout the main trail within the park. At each location, soil samples were collected with a soil corer (~1in diameter) penetrating the soil surface approximately 12” deep. A single core was taken at each of the 5 paired plots where wheeling presence was evident and also in a bordering forest to the trail that had not been used. The five plots were chosen randomly on the site map, Figure 1, when initially arriving at the site. The tests that were constructed of the collected samples were a % soil moisture test, water infiltration sampling, percent organic matter, and soil structure.

Field testing for the sampled sites of Cliffs Insane Terrain was water infiltration sampling. This was taken in order to measure the infiltration of water between a heavily compacted soil which has been driven on constantly by OHV vs. a soil in which has not been disturbed by OHV. First, a Campbell soup can with the bottom cut out (~2in diameter) is driven approximately 1in into the soil surface. When hammering the can into the surface of the soil, be sure that there are no openings at the bottom in which water can escape skewing the time scale in which water absorbs. Once the ring was placed, ~100 ml of water was poured within the Campbell's soup can while then starting the stopwatch. The stopwatch was then stopped after all the water had been completely infiltrated into the soil leaving no standing water within the soup can.

Lab Testing

Measuring % water moisture in the driven and non driven locations is an indicator for strength and structure because if the soil is highly compacted then it will have an increase in % moisture due to no capillary action within, for water to reach the surface. The soil core was driven in 12" to sample the main compaction zone from these vehicles. The main zone depending on the soil type at the site being sampled which should be compacted would be from the soil surface till approximately 12" depending on how badly the soil has been compacted from the Off-Road Vehicle (ORV) (Adams et al. 1977). The comparison of the two plots the will allow us to see the differences between eroded soil which has been constantly compacted by ORVs and soil which has not been disturbed by anything unnatural to its environment. Therefore, each of these steps was repeated twice at each of the five plots within the terrain park to sample the disturbed and undisturbed paired plots. First, the soil core was driven into the surface of the soil until the core was approximately 12" deep. Then, the core was removed slowly while trying not to lose any of the soil that was collected within the sample. After the soil was removed it was placed inside of labeled ziplock bags. Additional surface soil was removed and placed in a separate ziplock for use in other tests, including assessments of moisture, organic matter, and structure. After all the soil was collected at each individual site it was placed directly in a cooler to maintain a stable temperature for transport back to the lab.

When arriving back at the lab the soil samples were organized by each individual site to set up the preliminary testing of the soil samples to test the strength and structure of the soil. Drying the soil samples of driven vs. non-driven sites gave results of how the compaction from OHVs use on soil can change % water moisture. To dry the soil samples that were collected, approximately 10g was measured including the weigh tray which weighed ~1.3 g each. All of the weights were then recorded in grams labeled as the wet weight of the soil. After all of the sites were weighed, labeled, and recorded, the oven was then set at 65°C. Then place all of the samples within the oven and leave them in the drying oven for 24hrs until the dry weight can be recorded. After 24hrs of the sample being dried out in the oven, each sample was then weighed again to collect the dry weight of the soil and recorded.

The next test in the lab was to conduct how much organic matter was present within the soil samples that were collected in both the driven and non-driven sites. Using the soil that had already been previously dried out from the % moisture sampling, it was weighed out on the scale. When weighing the soil, the crucible weight was measured in order to identify the correct weight of the soil. In each crucible there was approximately 2g of dried soil that was put in for each of the sites. After all 10 sites were collected and weighed within the crucibles; they were then placed inside of the furnace. The furnace was then set at 450°C for 3 hours. When putting the soil into a furnace it should burn off all the organic matter present in the soil and tell us if there were roots or similar organic matter in the soil sample.The samples were then removed with extreme caution with tongs. They were reweighed to calculate mass differences between each paired plot to get the organic matter. To equation used to calculate the organic matter within the soil sample was Organic matter= (before furnace soil weight + crucible) - (after furnace soil weight + crucible). If the sample is spilled then restart the experiment in order to get accurate results.

Using the core samples that were taken at each of the paired plots, a soil kit was able to be used in order to test the soil structure. This test allows a comparison of the driven and non-driven areas to see what type of soil is present along with its makeup. For each of the 5 paired plots, each step was repeated. First, 15mL of soil was measured and placed in tube "A." 1mL of texture dispersing reagent was then placed in tube "A." Tube "A" was then filled up to 45mL with water and the top was closed. Shake for two minutes, making sure that the soil sample and the water are thoroughly mixed. Place tube "A" back in the rack standing undisturbed for 30 seconds. Then carefully pour off all the solution into tube "B." Allow tube "B" to stand for 30 minutes. The pour off all of the solution from tube "B" into tube "C" and return tube "B" to the rack. Next, add 1mL of the soil flocculation reagent to tube "C." Capping tube "C" gently shake for one minute and place back on the rack allowing the clay to settle. Then calculate the percent of sand, silt, and clay to be compared to a soil chart which will give the structure of the soil.

Differences between soil moisture, organic matter content, and infiltration rates on driven vs. non-driven locations were assessed using t-tests. A p-value less than .05 would show that the soils associated with the two terrain types significantly differ from each other.

Results

Since opening its doors in 2003 Cliffs Insane Terrain has become the main terrain park in central/northern Illinois. The driven terrain produced a greater increase in soil compaction than did the non-driven soil which has remained virtually untouched. The soils throughout the terrain park were very similar to each other because they all had a strong composition of clay both on the trails and off the trails which allows the ground to be held strong. In the non-driven areas which were more forested and plentiful in vegetation, along with an obvious trend of change in soil types. (Table 1) There was a very high concentration of clay which, when out at the site sampling soil for the driven terrain, it was almost like cement and seemed to be very difficult for any water to infiltrate nor plant to take root. However once through the first ~4in of clay there was an abundance of a clay loam soil.The heavily vegetated soils which were not driven on contained a heavier based loam soil rather than the dominately present clay soil on the driven terrain. The loam soil will allow better growth of vegetation because the roots can easily move through this soil as compared to the cement like clay soil present on the trails.

Table 1: Shows the differences in soil types at each of the sites both on driven terrain and non-driven terrain.

Plots	Soil type - Driven	Soil Type –Non Driven
1	Clay	Clay/Loam
2	Clay/Loam	Silt/Clay
3	Clay	Loam
4	Silt/Clay	Silt/Clay
5	Clay	Clay/Loam

The spatial distribution of this area is very easily identified when present at the site. The majority of the soil composition that is at The Cliffs Insane Terrain which showed up in almost every sample was clay. On the trails a heavy dominance of clay was present, but once off the driven terrain there were different compounds of soil. The vegetation in the non driven terrain compared to the driven terrain was higher because vegetation growth in soil depends on not just structure and stability but factors such as soil moisture, drainage, infiltration of water, and aeration. The clay soils found at this site are usually prone to higher rate of puddling and compaction because of the soil particles high plasticity and adhesiveness between each other. When clay soils puddle they typically become very dense and hard. Sampling plots closer to the riparian area of the site, soils became more moist and soft with a higher sediment build up along the banks of the stream from being transported. This might have happened from crossings upstream where vehicles drove through the creek to reach the other side, ultimately washing mud off the vehicle from a previous trail which is linked through a few creeks/streams in the park.

Infiltration of water within soil on both driven and non-driven soils with a p-value of .155 was shown to not be significantly different. The compaction of the soil shown by the amount of water the soil held however, was still shown to be greater within the driven terrain. The time it took for water to infiltrate to the soil at each site sampled was greater at the driven sites which suggests that there is a greater potential for excess runoff and for water to pool up which can lead to vehicles causing more destruction to the soil because the soil will then get rutted out and potentially be turned into a mud pit. The more clay based soil on the driven sites does not infiltrate water nearly as well as the the sites in which are non-driven which contained more of a silt clay and clay loam type. The clay as the surface soil had the greatest effect on infilitration timing for the test.

As seen in figure 1, there was a steady difference of water infiltration between both areas sampled at each of the sites. infiltration at each of the driven sites were similar to each other because of the compaction of the soil from the vehicles. When testing in the field it was obvious that the compacted soil of the driven terrain took more time to infiltrate vs. the non-driven terrain. The soil for the driven terrain had an average of 80 seconds for the water to infiltrate the surface completely, while the non-driven sites took only an average of 38 seconds in order for the water to infiltrate the surface completely (Figure 1). The average of infiltration for driven terrain was relatively high because at site 3 there was a significant increase in the time it took for the water to infiltrate the surface. If site 3 had not taken 180 seconds to completely infiltrate the soil, the average for soil infiltration would be 42 seconds. This shows that there is a very slight difference between the two terrains, but not nearly as great as it would be if site 3 had not taken so long to infiltrate the surface. Even though there was a difference between the driven and non-driven sample plots, there was statistically no significant difference with a p-value showing .155.

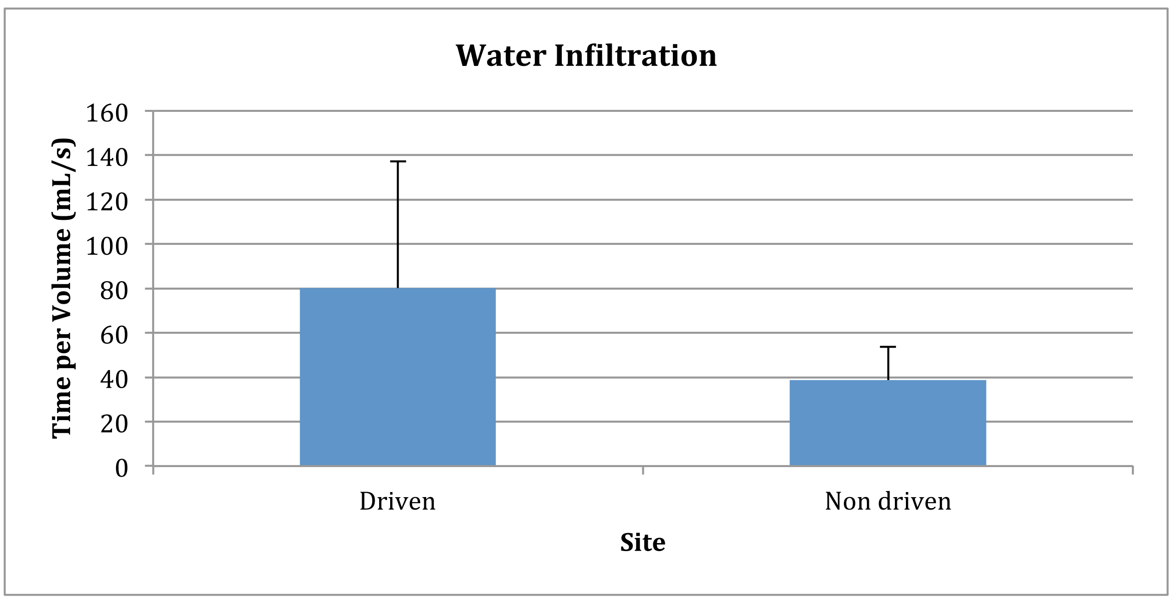

Figure 1: Water infiltration sampling, showing the mean/STD error of both the driven terrains and non-driven terrains.

The increases in compaction of the soil, produced in the driving areas in comparison to the non driven plots were not significantly different obtaining a p-value of 0.655. The driven terrain soil resulted in an increase in compaction due to OHV making passes continuously. The soil compaction is identified through Figure 2 because the water retention of the soil at each of the sites was measured by comparing the wet and dry weights of a soil. The water weight of the soil was higher because the soil was compacted not allowing the water to freely move throughout the soil through capillary action. The soil samples for driven terrain contained a relatively higher percent of water weight which shows that these soils are more compacted than the non-driven terrain (Figure 2). The soil that was on the trail for both of these sites was a very heavy clay soil type, while the soil type that was off the trail sampled for non-driven was more of a clay loam with lots of vegetation to absorb the water being taken in by the soil (Table 1).

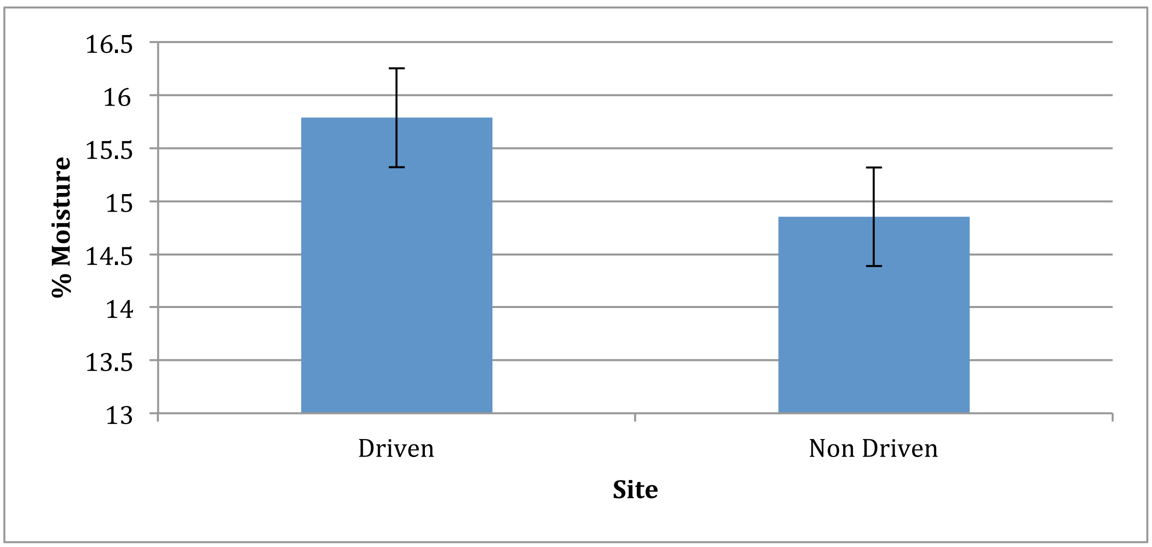

Figure 2. Mean and standard deviation of % moisture from driven and non-driven terrain.

The average percent organic matter was higher in non-driven areas compared to the driven terrain. This was correlated with the observation that more vegetation grew along the forested edges of the terrain which is where the non-driven soil samples were collected. The driven samples that were collected at each of the sites, were directly on the trails where there was little growth of shrub grasses or no growth at all. In the % organic matter there was a difference between the driven and non driven plots, but once again there was no significant difference. The basic t-test showed a p-value of .391which is still not below .05 describing it as not being a significant change.

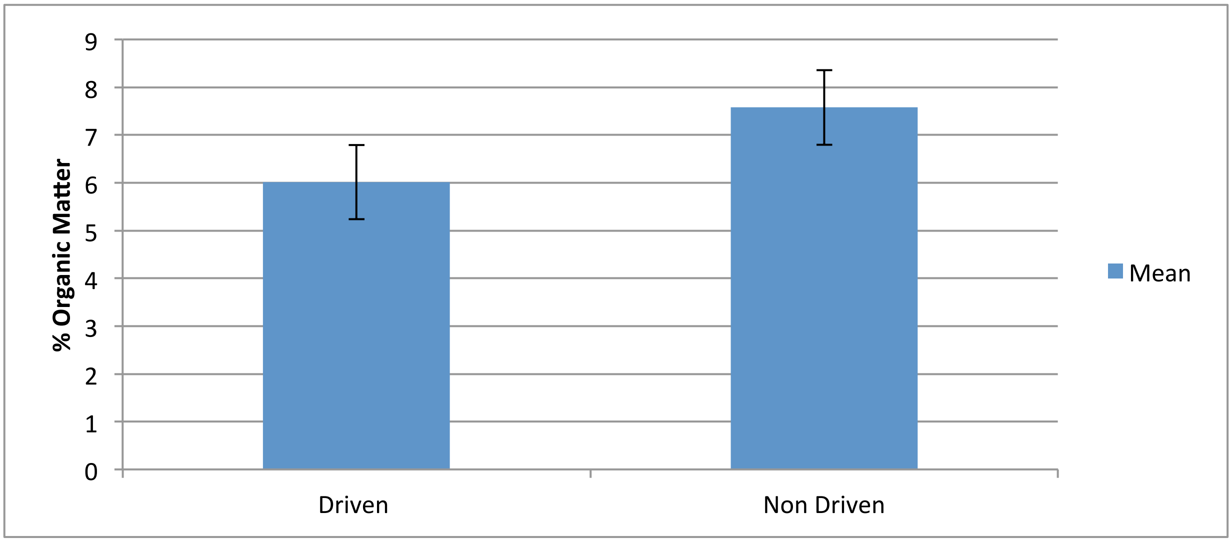

Figure 3: Percent organic matter present at each of the sites within the soil samples from both driven and non-driven terrain

Discussion

The data does not support the hypothesis because there is was no significant difference observed between soil properties associated with driven and non-driven locations. However, this can also be observed as an area that could have possibly seen its damage from years of wheeling or possibly altered by maintenance. Measuring moisture and organic matter produced a good comparison between the two different terrains. By measuring this, it showed that although there may not be a significant difference, there was a difference between driven and non-driven areas. When % water moisture and water infiltration were high, it correlated to the decrease in % organic matter within the soil. This made it apparent that there was definite compaction and erosion happening in the soil which was allowing the clay type soil to hold in water not allowing any capillary action for plants to grow and absorb the moisture within the soil.

The methods in which the test were taken could have been a little bit more precise, because after collecting all of the samples and analyzing all of the data I mistakenly thought I was performing a bulk density test when a different type of water moisture test was being sampled at each of the plots. Another piece that could have made the data more accurate was to take multiple readings throughout the course of a couple months. This would allow weather change, to get on/off maintenance schedules of the land, and possibly sample after huge wheeling events. With these variables, it would allow the data to fluctuate differently possibly allowing more test to be performed in both the field and the lab. When I went out to sample the soil the ground was colder and moist due to the data being collected in late October just after a good amount of precipitation from the weekend before. This could have possibly skewed the infiltration data along with the % moisture due to the weather.

The increasing number of OHV riders compounded with the problem of decreasing riding areas has caused many agencies to begin development of best management practices (BMPs) which should reduce the amount of soil erosion and sediment loss on trails. Understanding the factors causing the decline of an ecosystems health in recreational areas may lead to solution of many problems concerned with development and maintenance of trails. Wheeling can lead to a heavy impact on the environment if unregulated and maintained by organizations or the hobbyist for this activity that do not follow the one golden rule of wheeling which is minimal impact driving. The concept of minimum impact wheeling is coined in the off-road world meaning, that no matter what terrain encountered, there must be the least amount of environmental impact on the terrain that was used by these vehicles. Although a concept that may seem difficult to do in large vehicles, there are many unknown guidelines in which this community follows to minimize its impact by traveling responsibly on designated roads, trails or areas. Rooney (2009) has written down some BMP in which many OHV users follow to maintain the minimum impact wheeling.

- "Drive over, not around obstacles to avoid widening the trail.
- Cross streams only at designated points, where the road crosses the stream.
- If wet areas are encountered on established trails, go through them rather than around, if possible.
- If possible in soft terrain, go easy on the gas to avoid wheel spin, which can cause rutting.

- Minimize soil disturbance; it may promote invasive plant seed germination and establishment.
- Don’t turn around on narrow roads, steep terrain, or unstable ground. Back up until a safe place to turn around has been found.
- When attaching towing cable, tree strap, or chain attach as low as possible to the object being winched. Let the winch do the work.
- When using a tree as an anchor, use a wide tree strap to avoid damaging the trunk of the tree.
- Avoid sensitive habitats like living desert soils, tundra, and seasonal nesting or breeding areas.

- By wheeling in non invaded areas, you may introduce invasive species by carrying seeds. Do not create your own trails on public lands.
- Before and after a ride, wash vehicles to reduce the spread of invasive species into other areas”

When sampling data at the Cliffs Insane Terrain the trails there were continuously driven on were distinguishable from the non-driven areas which remained untouched by any OHV, but not significant (Figure 1, 2, 3). The trails at the park were very wide and continuously driven on, so the damage to the land such as downed branches and invasive vegetation growth is minimized. With the regular maintenance of the land and the trails being widened it allows the impact to the surrounding environments to be kept to a minimum. Having these trails maintained constantly can create a fallacy within the results of the sites being measured. With these sites being continuously grated, it makes measuring compaction of the soil on the driven trails difficult. This could explain the lack of significant soil difference between the two terrains (Figure 1, 2, 3).

Surrounding the Cliffs Insane terrain in Marseille, IL there are very few terrain parks both privately and publicly where it is legal to off-road on a regular basis. Wheeling within the Midwest area is usually going to be on private lands within terrain parks which are constantly monitored by the people who own the land. These privately owned parks are usually very large in size and located out within the country setting far away from the big cities, where maintenance is always necessary. For example the two main parks within the Midwest that hold majority of the wheeling events for different organizations are the Cliffs Insane Terrain (the area that was studied in my research) and the Badlands in Attica, IN. Both of these parks span a vast area varying from 300 acres to 700 acres consisting of many different terrains and trails that any off-road vehicle can be a part of. Both of these parks are maintained regularly by both patrons and staff with some funding and grants given by government associations. These grants provide the funding to maintain with heavy machinery which allows them to grate the soil routinely along with filling in ruts created by vehicles wheel spin after heavy precipitation on the land. Apart from the privately owned lands, there are still public places which wheeling is available. However, this land is monitored sparingly depending on the location of the site by government organizations such as the BLM or the Department of Natural Resources (DNR).

There are many differences between public lands along the West coast and wheeling in the Midwest (Strittholt 2002). Out along the West coast, there is a heavier population/interest in wheeling so the lands are used more frequently by these OHVs. Therefore maintenance by government associations will have a greater input in the upkeep and grooming of the lands than they would in the Midwest. In the Midwest the maintenance among public lands is a lot different for the reason being that there is no money being collected from permits or daily wheeling fees in order to fund the routine maintenance for government associations.

There are over 30 organizations of OHV associations located within the Midwest currently. A majority of these organizations are very interested in the health and status of the lands that they wheel on. Because of this, each of these associations at least once a year will organize a volunteer clean up both the public lands and sometimes private. Usually organized by specific agencies, groups of people in the off-road community gather to go through the trails and upkeep the land for many reasons. If a government agency such as the DNR or the BLM checks on the land and sees the land has sustained damage from wheeling, then it will shut down the public access for these vehicles in order to preserve what is currently there.

In conclusion, it was not supported by the data that there would be a reduced amount of organic matter and precipitation infiltration in the soil of Cliffs Insane Terrain which had been constantly wheeled on through the years. However, BMP's of wheeling and constant maintenance of the soil should minimize the damage causing less erosion and compaction as compared to non-driven terrain.

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