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**Topsoil losses in Ohio due to agriculture and how to impede it: a review**

**Abstract**

Soil erosion poses a monumental threat to Earth’s waterways and geological makeup. Agriculture is the leading offender in the loss of soil, particularly in rural areas, contributing not only earth deposits to the waterways but also high counts of nitrogen and phosphorous. Soil erosion leads to depleted agricultural land, pollution, eutrophication, and degraded quality of living for macroinvertebrates, fish, aquatic vegetation, and many more. Ohio lands, being approximately 50% agricultural, some of which are located within floodplains, are no exception. Much of the midwest is considered to be the “Corn Belt.” Environmentalists and farmers alike are looking for ways to combat erosion and degradation, be it for crop yield or conservation and preservation of the land and its resources.

**Background**

It is important to note that there are two main types of soil erosion, generally known to be normal occurrences through wind and rain. However, soil erosion has been exacerbated by humans and poor conservation tactics (Bhandar and Darnsawasdi, 2014). Erosion poses a threat to both water and land. Due to poor land management, wind and water erosion have degraded the land and lowered stability and sustainability of land. This lowers crop yield, the economy, and environmental impacts steadily rise to the detriment of the planet in both diversity and abundance. (Pimentel, 1995.)

When rain falls, the droplets have a high impact on exposed soils, hitting hard enough to throw soil particles into the air with each impact. Erosion due to water and rainfall becomes more virulent on slopes, falling in the form of splash erosion, one of the two main forms of erosion, the other being sheet erosion. (Pimentel, 1995.) Rainfall soil erosion depends on geological elements, including the properties of the soil, ground slope, the vegetation of the area, and rainfall in amount and intensity (Montgomery, et al. 2007.) Soil erosion due to rainfall can occur through three possible routes: surface runoff, subsurface runoff, or groundwater flow (Azzi, et al., 2016).

As human populations rise, however, the need for more crop and grazing land increases. This results in more loss of forested lands to agricultural land. As humans have already converted flatlands to agricultural uses, this leaves most new lands to be steeper in slope. Thus, erosion rates increase, as steeper slopes are used and the soil becomes exposed. (Pimentel, 1995.)

As soil erodes off of crop fields, it carries the pesticides, herbicides, and trace elements with it. It is noted that phosphorous and nitrogen inputs exceed the output of produce in the United States, and that both contribute greatly to the eutrophication of lakes, rivers, estuaries, and coastal oceans. Nitrogen appears to be the most responsible element for the eutrophication of estuaries and coastal ecosystems, and phosphorus also has an essential role in coastal eutrophication. Eutrophication of aquatic ecosystems leads to an increase in algal blooms, and some aquatic weeds. Both inhibit aquatic agriculture, and can result in low oxygen levels that lead to mass fish deaths. The increased levels of nitrogen and phosphorous have degraded aquatic ecosystems and impacts human use, including but not limited to drinking, recreation, and agriculture. (Carpenter, et al. 1998)

A simple way to measure the health of waterways is to study the macroinvertebrate life within the waterways. This is usually tested by going into the field and using kick-nets in riffle and deep areas to capture macroinvertebrates and fish. Health of the stream can be analyzed by taking into account species richness and abundance. Certain species are more susceptible to pollution, while others have a high tolerance. If there is a higher count of species overall, especially if they range in the low-tolerance for pollution, the more healthy the stream. It is also to be noted that the organism count can fluctuate depending on agricultural runoff. If there is more runoff, it follows that there will be fewer organisms in a catch. (Lenat, 1984)

Wind erosion is also caused by loose and exposed soils. Winds will pick up and transport soils, sometimes thousands of miles at a time. (Pimentel, 1995.) One extremely memorable series of events caused wind erosion on a massive scale: the Dust Bowl. The term was coined in the 1930’s, and focused on an environmental event that started in the Great Plains of the United States, with a central core with the most severe storms in pieces of Kansas, Colorado, Oklahoma, Texas, and New Mexico. (Carman, et al. 2016.)

The Dust Bowl is thought to have started in response to a severe, ten-year long drought, and the dust storms increased in magnitude and frequency. Dryland farming was being used to farm the Great Plains. Soil was packed approximately 0.1 meter below the surface, and the topsoil was used almost like mulch to avoid evaporation and was comprised of loose soil. To get the desired topsoil, farmers frequently tilled their fields. At the time, moisture in the soil was much more important to the farmers than erosion control. Thus, when the drought hit and farmers were doing what they could to maintain moisture in the soil, the topsoil was frequently “mulched”, which aggravated wind erosion. (Carman, et al. 2016.)

The Dust Bowl is an extreme case of wind erosion, though it is not the only example to draw on. It happens in normal and aggravated rates, most notably in arid and semi arid regions around the world. (Carman, et al. 2016.) Ohio has some effects, especially with the lack of windbreaks; however, runoff due to rain is the most researched in Ohio, so this will be the main review of the paper.

Northwestern Ohio was once a deciduous swamp forest, known as the Great Black Swamp. As people went west, they found it daunting and began to cut down the trees, which is indicative of what followed throughout Ohio. The first surveys of Ohio were taken in 1786, and show that the dominant forest from the northeast to southeast was made up predominantly white pine and hemlock. (Sears, 1925) It is estimated that around fifteen hundred square miles in Ohio were naturally prairie, and lacked trees before settlers moved and started to colonize the state. (Sears, 1926)

As of 2014, there were 74,500 farms in Ohio, which take up 14 million of the state’s 28.8 million acres. (Turner and Morris, 2015.) Not unlike the rest of the United States, Ohio’s land degradation is due in large part to agricultural land use. The crop lands throughout the midwest have been shaped and cultivated largely for corn and soybeans has intensified erosion. (Young, et al., 2013)

 High amounts of nitrogen and phosphorus in watersheds can result in the rise of algal bloom, as they are known to be limiting factors in algal growth. When the algae dies, it is hard to decompose all the dead matter, and anoxic conditions rise. The Great Lakes Water Quality Agreement of 1972 was set up between the United States and Canada and used to remove phosphorus at municipal and industrial plants. It seemed to work at first and Lake Erie was considered to be a success. ( Baker, D. B. et al, 2014)

However, Lake Erie has reached record-setting algal blooms several times in the last decade, starting in 2008 (Michalak et al., 2013). The bloom in 2011 was nearly twice that of 2008, and 2015 topped the bloom of 2011. In 2015, toxic blue-green algae covered approximately 300 square miles of Lake Erie’s surface (Moore, R. 2015). The 2013 study hypothesized “that trends in agricultural land use contributed to the 2011 bloom. Corn cropland increased 11% nationally and land in the federal Conservation Reserve Program (CRP) decreased 14% between 2008 and 2011.” (Michalak et al., 2013.)

Lake Erie is an obvious example for the runoff and pollutants near Ohio, but it is not alone. The Ohio, Mississippi, and Missouri rivers all feed into the Gulf of Mexico. The hypoxic conditions have led to the eutrophication of the gulf, and 90% of the nitrogen influx are contributed by the midwest. Agriculture plays a large role in the runoff, though urban runoff such as the nitrogen in detergents also adds to the hypoxic conditions. (Mitsch and Day Jr., 2006.)

Nitrogen and phosphorus loading into lakes are fed in large quantities by rivers and streams. These bodies of water should be studied to see their levels and their progression of eutrophication. In lotic zones the relationship between nutrients and chlorophyll, and therefore algal biomass, are generally weaker. There are very few studies that cover the eutrophication of streams and rivers in comparison to lakes. (Dodds, Smith, and Lohman, 2002)

While there are few studies of eutrophication in rivers and streams, researches have started to analyze what may have been exacerbated anthropogenically. One study narrows these effects down to the excessive growths of algae and macrophytes (though there has been a reduction in macrophyte species diversity), a diversion of macrophytes to benthic, filamentous, or planktonic algal dominance. It also notes frequent lows in dissolved oxygen levels, usually overnight, high pH changes, more blue-green algae, and a change in water color to green or brown. (Hilton, et al. 2006)

This study also breaks down where algal blooms occur and in what frequency they occur. Planktonic algal blooms are unlikely to reach high, or nuisance levels at the source of the rivers or streams because of the fast flow. This is also likely to reflect in shorter rivers, with shorter retention times. However, larger rivers or deep rivers have long retention times, more along the retention rates of lakes. The algal blooms in these larger rivers can develop in the middle, deep parts, or the mouth of the river where it dumps into a lake or ocean. If the river is fed by a eutrophic lake, however, the algal retention rate will be higher. In shorter rivers, these blooms will not increase significantly. Larger, longer rivers however have the potential to increase and amplify the effects of these algal blooms. (Hilton, et al. 2006)

**Erosion Controls**

There has been an increase in rainfall in the midwest in the past few decades, with climate projections indicating much the same in future. Ohio is looking at more precipitation and more flooding events. Growing season is likely to change as well as the makeup of the soil in saturation and possible crop-loss in severe drought events. (Young, et al., 2013.)

 Some management practices for erosion control that have been proven to be effective “include ridge-planting, no-till cultivation, crop-rotations, strip cropping, grass strips, mulches, living mulches, agroforestry, terracing, contour planting, cover crops, and windbreaks.” (Pimentel, et al. 1995.) Each method is used by a regular and maintained vegetation cover to protect the soil from exposure. Many control practices include reduced tilling of the fields, which expose the soil. (Pote, et al. 1996.)

Ridge-planting holds the soil together by planting crops in the ridges created from the last crop. This process reduces the need for a more frequent till rotation. It also ensures a constant vegetative cover on the land year round, lowering soil exposure. (Pote, et al. 1996.)

No-till cultivation is effective for farming in that it can help the land retain moisture. The earth remains packed down and is less likely to be swept away by wind or water erosion. However, the disadvantages of no-till includes reliance on herbicides, and there may be a delay in planting, courtesy of the higher moisture content in the soil and subsequent lowering of the soil temperature. ( Buchholz, et al.)

Crop rotation applies a systematic approach to applying certain crops certain years. This allows for more fertile soil and a recuperation period after a crop that depletes the soil. It is advised that crops should rotate with wheat, oats, alfalfa, and others as well as corn and soybeans. Studies of crop rotation have revealed that multiple crop and year rotations have yielded higher crop production. The crops have also proven to be more resistant to pests and rely less on fertilizers and pesticides. (Healthy, 2017.)

Grass strips are the act of putting in a vegetative barrier, normally a grass or hedge strip, approximately 1 to 3 feet wide. This system is used to inhibit water flow and reduce soil erosion. Very similarly, the United States Department of Agriculture has defined vegetative filter strips, which are used to filter nutrients, pesticides, and soil from the runoff. The width of these strips must range from 15 to 30 feet to ensure trapment. (Kika.)

Mulching is the act of using organic or inorganic matter to be placed on top of crops or in between rows. Common mulch materials include, though aren’t limited to straw, tree bark or wood chips, and shredded newspaper. A study on Prince Edward Island in Canada gives evidence that mulching techniques in fact cut soil erosion in half in mulched plots versus unmulched plots of a potato crop, though mulching had no effect on crop yield. (Edwards, et al., 2000.)

Trees and shrubs are grown in tandem with crops and pastures to make a healthy agroforestry system. The tree canopy protects much of the ground from rainfall abuse, lowering the impact of the striking power to loosen the topsoil. However, it is noted that, “The greatest potential of agroforestry lies in its capacity supply and maintain a ground cover.” The canopy part of the agroforest not only lessens rainfall impact, but also supplies groundcover with leaf litter and tree prunings. (Young, 1989.)

Building a embankment of earth on a slope will reduce soil erosion. This action is referred to as terracing. The terraces reduce the steepness of a slope, and directs runoff and water in a desired direction, and reduces the peak discharge into watersheds. Terrace efficiency depends on where it is implemented, and increases when used in tandem with other conservation practices. (Dorren and Rey, 2014.) Contour planting is also used on hillsides, but instead of building terraces, crops are planted lengthwise perpendicular to the slope. This practice helps to keep topsoil in place. It slows runoff, allowing the soil to absorb the water rather than just draining. This also improves irrigation. Contour planting is also most effective when combined with other conservation practices. (United States Department of Agriculture)

When fields are harvested, sometimes farmers will plant cover crops to alleviate soil erosion after the removal of the summer crop. These crops act as a blanket almost for the soil, protecting it from rain and runoff. It reduces the crusting of the soil surface that can occur with a lack of organic matter to bind the soil. It can also break up the hardpan and set up the soil for the next crop rotation. (Cornell, 2009)

Windbreaks reduce wind speeds, but are dependent on tree and shrubbery height, length, location and density. These windbreaks can alter their sheltered regions. They can moderate soil and air temperatures and increase the relative humidity. It lowers evaporation and increases soil moisture. The windbreak application has a double advantage: with the break it reduces the effects of winds strong enough to move and carry away soils, and the increase of soil moisture acts as a binding agent to hold the particles together, which lowers the likelihood of the wind being able to pick up and transport them. (Grand River Conservation Authority, 1994)

**Discussion**

It cannot be denied that nutrient loading into fresh and saltwater systems has detrimental effects. The eutrophication of Lake Erie has been well studied and analyzed. It is known that much of the algal blooms are encouraged by the nitrogen and phosphorous loading into the waterways. From here, soil conservation practices must be reviewed and adjusted accordingly. The following are proposals for new, combined efforts in conservations practices to combat soil erosion in the Ohio landscape, Based upon where the practices are to be utilized. Refer to figures one (McDonald, J. et al, 2013) and two (Geoscience News and Information in the appendix to see the topographic and river makeup of Ohio.

 In northwest Ohio, where the glaciers ages past flattened and scoured out a flat land, there is very little change in elevations. Formerly the land of the Great Black Swamp, the soils were very rich and were used easily once cleared. It also includes two major waterways that dump into Lake Erie; the Maumee and Sandusky.

 Advised conservation practices for northwest Ohio would include or be a combination of windbreaks, grass strips, crop rotation, cover crops, and mulching. All of these practices can be viewed in this area already, but they should be more regulated and increased. For example, each field should have a windbreak along the edge where the strong winds normally blow from. They should have wide grass strips of approximately 15 feet, which should not be mowed so as to create more of a filter for soil and nutrients. Crop rotation and cover crops should be used to keep the soil naturally enriched and firm.

 Northeast Ohio has a little more elevation change in comparison, but is still relatively flat. The Cuyahoga River feeds into lake Erie as well, bringing with it more nitrogen and phosphorus. The northeast should also use mulching, windbreaks, grass strips, cover crops and crop rotation. In areas where the elevation changes more dramatically, ridge-planting should also be incorporated.

 Southwest Ohio falls into the glacial range as well. It also starts to have some rolling hills, and this should also include ridge-planting and perhaps some terracing practices to set up diversion routes for drainage from the fields into a soil trap. Perhaps it may be better to avoid heavily mulching near steep embankments, and to plant more in the form of agroforestry and vegetative filter strips.

 In southeast Ohio, the glacial rach finally reaches its end and the foothills Appalachia begins. Much of this area is dedicated to parks and national forests. There is less farming and more timber harvesting. However, for agricultural purposes, it would perhaps be better with more terraced and ridge-planting to control erosion. While there are more forested areas, it would make sense to have agroforestry practices utilized in the southeast.

**Conclusion**

 Most of Ohio is built in gradual elevation, so it follows that soil erosion practices should be relatively similar. Soil erosion conservation needs to be more of a controlled and enforced policy throughout Ohio, especially on agricultural and urban lands. More studies into truly effective conservation practices should be more readily available and in layman’s terms so as to be more accessible to farmers and private citizens.

 Farmers have been given incentive to set aside land for wetland cultivation, which is a beneficial practice, but more incentives should be given so as to encourage more conservation practices. Instead of planting as much as they can, sometimes up to two feet from a road or river embankment, they should be encouraged to plant vegetative strips and windbreaks.

 Future studies need to be made to measure the eutrophication of rivers as well. If they are a contributing factor to the nutrient loading, it follows that they should be heavily studied, at least as much as the lakes themselves. Clear and universal definitions need to be established for river eutrophication, and studies into the runoff from nonpoint sources need to be investigated. In conclusion, more study into waterways other than lakes need to be established and enforced conservation practices need to be set up if Ohio wishes to become more sustainable and not poison its freshwater sources.

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**Appendix**



**Figure 1**. USGS topographic image of Ohio, marking a bold line along the glacial boundary.



**Figure 2**. Geoscience News and Information map of the rivers of Ohio.