**Soil**

It isn't only the insects above land that are being affected by industrial agriculture. The problem is much worse, and the insect apocalypse has an equally pernicious partner in crime, soil degradation. Soil degradation is the term used for soil which has seen its ability to grow crops diminished. Soil isn't something that we think about regularly. It is largely reserved for children and green fingered gardeners. Soil is so important for our lives, however, that maybe it deserves a place in discussions at the dinner table.

Amazingly, the brown stuff contains at least a quarter of all global biodiversity and is essential for providing clean water. It also helps to prevent flooding and drought. Significantly, it plays a vital role in ecosystem nutrient recycling as organisms decompose and provide sustenance for other wildlife (209). Every single handful of healthy soil contains billions of microscopic organisms. If we were to take just a gram of soil, it would host up to a billion bacteria cells. Overall, around eleven million species of organism live in the soil and less than 2% of these have been named and classified. It is also a depository of many possible life saving medicines. Vitaly for humans, healthy soil provides healthy nutrients to plants, and these in turn provide healthy nutrients to human beings (210). It total, 95% of global food supplies are reliant on soil (211).

In the fight against runaway climate change, soil management will play a huge part in the success or failure of human beings to keep temperature rises within manageable levels as three times more carbon is stored in the soil under our feet than is in the atmosphere today. Research from 2017, found that better soil management has the potential to store more than 1.85 gigatons of carbon annually. This is more than all the carbon emitted by every plane, train, car, ship, motorcycle, helicopter and truck each year (212). Since the agricultural revolution, 133 bn tonnes of carbon has been emitted from the soil, and this number has increased rapidly since the beginning of the industrial revolution. Around a quarter of all manmade carbon emissions to date have come from the soil under our feet, and interestingly, around a quarter of our carbon emission are absorbed by the soil annually (212). If the rest of this carbon is released, we can declare the fight against climate change to be over.

If we want to see the impact of losing topsoil, we can look at history. According to Roman tax records, Syria and Libya used to grow significant amounts of wheat, but as farmers degraded the soil over time, today these areas have barely any soil to grow crops. The effect of topsoil destruction is passed on to future generations as soil forms extremely slowly at the rate of one cm every 300 years, so once it's gone, it does not reappear in the lifetime of a generation, or even three (213). To be brief, according to soil expert, *Prof Jane Rickson*, from *Cranfield University*, UK:

*"The thin layer of soil covering the Earth's surface represents the difference between survival and extinction for most terrestrial life. (214)"*

We have seen how important soil is for our existence, but why should we be concerned about the earth in our gardens? At present, according to *Volkert Engelsman* from the *International Federation of Organic Agriculture Movements*:

*"We are losing 30 soccer fields of soil every minute, mostly due to intensive farming (1)."*

According to the *United Nation's Food and Agriculture Organisation* (FAO), soil degradation is a bigger obstacle to human survival than global warming, species loss or any other environmental crisis. They warn us that twenty-four billion tonnes of fertile topsoil are lost each year, and that 25% of the Earth's surface is degraded already. This is enough land to feed 1.5 billion people (215). The *World Wildlife Fund* (WWF) states that half the world's topsoil has disappeared in the past 150 years (216).

Mozambique, as we have seen, was hit by intense storms and droughts in 2019. As if this wasn't enough, they also had to deal with the loss of 400 sq. km of cultivated land due to the use of pesticides (217). Further north, soil degradation in Ethiopia is believed to cost the country US$4.3 billion annually. The problem of soil degradation isn't shared only in developing countries. It is estimated to cost Italy around €900 million a year (218). In Iowa, America, the depth of topsoil has diminished rapidly since 1900 when the depth was 35-45 cm. By

2000, this depth had declined to 15-20 cm. More worryingly, is that in the still-fertile fields in Iowa, more than 14 million tonnes of soil were lost in 2014 due to a series of storms. The state university analysed eighty-two sites in twenty-one counties and discovered that from 1959-2009, soil structure and levels of organic matter had degraded and acidity had increased (219). In the U.K., 2.2 million tonnes of topsoil are eroded every year and 17% of land has already been eroded, with 44% of arable land at risk. About 18% of organic matter in the arable topsoil was also lost between 1980 and 1995. Experts warn that organic matter levels are so low that in the long term, food production might not be sustainable (220). Organic matter is essential for healthy soil. It provides nutrients and habitat to organisms and helps soil hold water. It would be possible to spend many more pages dedicated to soil degradation, and it is clearly an existential threat going forward. However, the FAO summed up the problem facing humanity due to soil degradation in a much more succinct way. They released an astonishing statement at a forum marking *World Soil Day* in 2014, where *Maria-Helena Semedo* stated that if soil degradation levels continue apace, all of the world's topsoil may be gone by 2074 (1). The problem is global in scale, and unless it is tackled head on, it could combine with other factors to make life on planet Earth very inhospitable.

Erosion of soil is also a massive problem exacerbated by the climate crisis. Areas that have traditionally experienced erosion will likely see much more in the future. Rainfall distribution and intensity are affected and with greater rainfall in shorter periods, erosion is likely to increase. Sub-Saharan Africa is already suffering from the erosion of its soils, with erosion accounting for 77% of overall degradation. 22% of arable land is at risk. Almost 70% of Uganda's land has been degraded by erosion, areas of grazing land have been devastated in Tanzania and Malawi loses 29 tonnes per hectare of land each year to erosion. The problem is not contained to Africa. 7.2% of Europe's total crop land is impacted at a cost of €1.25 billion ($1.4bn) annually (221).

So, how did we get into this mess? As was the case with the spread of DDT, the initial cause of this problem was extremely well intentioned. It can be traced back to March 25, 1914, in Saude, Iowa. On this day, a boy was born who would go on to save the lives of hundreds of millions of people, and in the process win

the *Nobel Peace Prize*. *Norman Borlaug* was born into a hard-working family of Norwegian ancestry. He grew up poor and helped his father farm potatoes and raise cattle. Every autumn, his family handpicked half a million ears of maize on their family's forty-acre plot. In 1932, Borlaug decided to attend the *University of Minnesota* where he was offered room and board in return for working as a waiter in a diner. He duly became shocked by the effects of the Great Depression. Buildings were abandoned and streets were filled with the homeless victims of the dustbowl. Many people wrapped themselves in newspapers in the absence of blankets. A lot of these homeless were former dairy workers kicked off their land after struggling to pay off debts. During World War I, the government had encouraged dairy farmers to increase yields to help feed the soldiers. High prices were paid for this milk, and in turn farmers bought more cattle and increased production. They also invested in tractors and pasteurization systems which placed them in debt. Unsurprisingly, after the war, demand plummeted, and farmers were left with high levels of debt, and no way to pay it off. They ended up selling milk at a loss, and eventually the banks foreclosed on them, and many ended up in Minneapolis. Fast forward to 1933, and Wisconsin was hit by massive discontent as people struggled to survive. Riots broke out and the young Borlaug witnessed this first-hand. There and then he decided that he wanted to make his life's work about ending hunger forever (94).

Borlaug studied forestry in Minnesota, but he ran out of funds in 1937 and began working as a forest fire fighter to improve his finances before taking a job with the *U.S. Forest Service* after his graduation. It was in university, that Borlaug would be introduced to the problem of black stem-rust fungus that was decimating wheat crops. This had been a problem for millennia, and Borlaug's family had actually experienced it in 1878 when they were driven out of business. Later in 1904 and 1916 it had led to widespread misery in America and northern Europe. Almost 1/3 of the wheat harvest was lost in 1904 which forced the bread prices up. The spores from the rust were carried high into the air by the slightest of winds and spread for miles. On just a single acre of wheat with moderate stem rust, more than fifty trillion spores were evident. The rust was such a problem historically that Romans were in the practice of sacrificing rust-coloured dogs to the Gods to appease them. In this rust, the young, and driven Borlaug, had found his cause (94).

During cold winters in the U.S. and Europe, the fungus cannot survive the cold, but in the warmer climates of Africa and Mexico, the spores are carried north by constantly blowing winds. It is in these winds that spores are brought north to meet the warming spring weather and settle on wheat crops. In 1914, the Rockefeller Foundation had succeeded in preventing the spread of cotton pests such as boll weevils. Decades later, the U.S. government was keen to assist Mexico in raising the wheat crop, but due to massive negative feelings towards the U.S., the government turned to the *Rockefeller Foundation* to help work under the radar. The foundation appointed three scientists to work on the problem, one of whom was *Borlaug's* professor from Minnisota, *Elvin C. Stakman*. Due to Mexico being the origin of stem rust in the U.S. *Stakman* was extremely interested in trying to eliminate it south of the border. Starting in 1931, work began in earnest. Soon, the scientists saw with their own eyes the desperate situation of the Mexican people who had little food, few clothes and had poor housing. At that time, the Mexican harvest had dropped by a third since the 1920s, even though they had planted almost a million more acres of wheat. To make matters worse, the population had risen by five million. The scientists worked hard to report back to the *Rockefeller Foundation* and a few months after they finally sent off their report, the Japanese bombed Pearl Harbour. In times of war, it was prudent for America to have a peaceful situation close to home. This led to the *Rockefeller Foundation* stepping up their efforts. Top of the list was improving maize production, but they also knew that if they could breed stem-rust resistant varieties of wheat in Mexico, that could cut off the rusts' path to wheat north of the border, thereby increasing yields, reducing hardship and improving food supplies for the troops (94).

Back in the states, *Borlaug* was obtaining his master's degree in 1941 after studying fungal disease for his dissertation. Sadly, he took no ecology, soil science or hydrology classes. If he had, the world may very well be a different place today. In October of that year, St*akman* called *Borlaug* to his office to invite him to accept a job at Du Pont chemical company in Delaware. His wife made sure he accepted the job as no other offers were on the table. In December they drove to Delaware and *Borlaug* began working on a variety of jobs for the war effort. He couldn't have been too enthused by his new line of work because

when *Stakman* offered him the chance to head up the stem-rust team in Mexico in 1943, he readily accepted. In September of the following year, he left for Mexico. He travelled the country looking at different varieties of wheat and farming techniques that seemed to prevent stem-rust. Scientists back in the U.S. sent many varieties for him to test in the Mexican soils. During this time, *Borlaug* was further concerned to see the poverty that existed all around him and the lack of healthy soil in which to grow wheat (94).

He continued his work at breakneck speed, cross breeding thousands of foreign varieties in the hope that one would be resistant to stem-rust. A full decade after arriving in Mexico, *Borlaug* finally had some success in producing a short variety that not only fended off stem-rust, but also produced more grain. The only downside was poor taste and low protein content. It took another five years of work to improve the taste and amount of protein, but by 1962, they had succeeded in producing a prolific short variety of wheat that was not only disease-proof but could also grow in soils that were rich or poor anywhere in the world. In this line of work, *Borlaug* and his team had found the Holy Grail. There were only two things necessary for the wheat to thrive and the harvest to be large, water and fertilizer. He believed that pouring on water and fertilizer would be the answer to worldwide hunger in growing larger than ever quantities of wheat (94).

Up until this point, the work of *Borlaug* is hard to criticize. It was from this moment forward that the problems we experience today, can be traced back to his influence. Borlaug offered a package that could be used in any country on any continent, seeds, fertilizer and water. Each would need to be adjusted slightly to suit each environment, but by and large the package remained the same, seed, fertilizer and water. In 1968, the term ‘Green Revolution’ was used to describe Borlaug’s package as it had led to crops in Mexico growing from 345kg per acre to almost 1,143kg in just twenty years. Harvest had tripled on Borlaug’s watch. Similar results were coming in from India and Pakistan, and his discovery certainly averted famines and saved many lives. People around the world rightfully applauded his incredible dedication and effort. In 1970, in gratitude for his many years of work, he was awarded the Nobel Peace Prize (94).

Unfortunately, *Borlaug's* package had two problematic features: water and fertilizer. Water was increasingly in short supply and these new crop varieties required more water than usual. Additionally, the fertilizer favoured by American corporations was synthetic and this led to long term declines in soil fertility, reduced genetic diversity and soil erosion. To buy this package, subsistence farmers got into debt, and many were displaced in favour of larger operations. The discovery of *Borlaug* also set in motion the wheels of the larger genetically modified seed companies to plant larger than ever monocrops that required fertilizer by the truck load. He also threw his full support behind the large-scale use of pesticides, even going as far to endorse the use of DDT in 1971, and in doing so denigrate the *Silent Spring* author, *Rachel Carson*. In response to concerns from environmentalists about the use of chemicals in our food system, Borlaug had this to say:

*"Because of unwise legislation that is now being promoted by a powerful group, of hysterical lobbyists who are provoking fear by predicting doom for the world through chemical poisoning, then the world will be doomed not by chemical poisoning but from starvation (222)."*

Unfortunately for *Borlaug*, his legacy may not be the one he worked long and painstakingly for. His miracle discovery, while providing incontrovertible short-term benefits, has led to long term degradation of our soils which ironically may be unfit to grow crops on the one hundredth anniversary of his Nobel Peace Prize.

As they say, hindsight is a beautiful thing, and in hindsight, chemical companies were not ideal bedfellows for a man with such lofty ideals. As *Borlaug* struggled under intensely difficult conditions to provide adequate food for the poor, his partners were locked in a war of manufactured doubt. As concerns arose about the safety of their products, their spin went into hyper drive. The same PR companies employed by the tobacco industry, and more recently, the fossil fuel industry were purchased to provide "evidence" that spraying chemicals on the food that we eat was safe. Multinational behemoths like *DowDuPoint, Bayer, Monsanto* and *Syngenta* insisted that their products were not only safe, but necessary to feed our growing population. In the fifty years following the end of

WWII, insecticide use increased by ten times in the U.S. In the same period, crop losses almost doubled (300). This hardly sounds like a necessary product.

The end of the war also coincidently saw a new market opening up for producers of nitrate. At the war's end, the U.S. had ten large-scale nitrate factories making bombs for the war effort. With the advent of peace, these companies looked elsewhere for a market for their goods. They settled on agriculture, and especially, the new hybrid strains that had been developed. By the mid-2010s America was responsible for 12% of the planet's nitrogen-fertilizer use, much of which was designated for corn which covers 30% of American farmland. Whilst nitrogen is essential for good soils, the excess nitrogen that comes from the synthetic kind seeps into streams, rivers and eventually oceans, in turn causing ocean dead zones. It also emits nitrous oxide, which is 300 times more potent than carbon dioxide, and more importantly for this section, destroys organic matter in soil (223). Research is suggesting that a simple shift to more diverse crop rotations would eliminate the need for artificial fertilizers while not affecting food production. Unfortunately, this is not happening. Fertilizer use is growing rapidly. More than 200 million tonnes was forecast to be used in 2018, a 25% increase in a single decade (224).

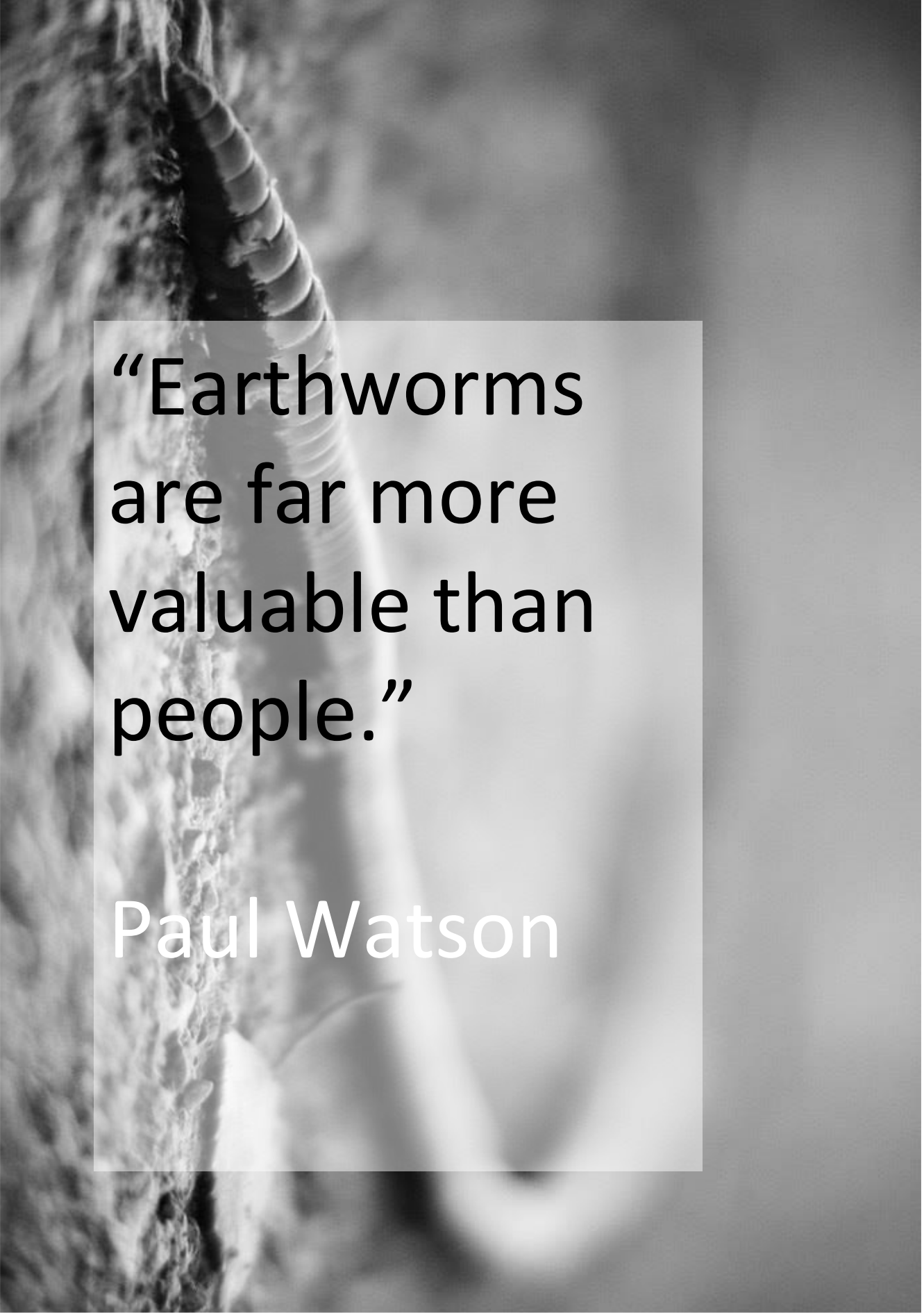
The industrialized use of pesticides on our food is impacting on the earthworms in the soil too. Earthworms in the soil under crops sprayed with pesticides only grow to half their usual weight and fail to reproduce as efficiently as earthworms where no pesticides are used (225). In the UK, two out of five fields have either too few or no worms at all, according to *Rothamsted Research*. In turn this has led to a drop in song thrush populations (226).

Agrichemical companies have long led us to believe that their products are vital to feed the burgeoning world population. However, it is becoming apparent that organic farmland helps to reduce soil degradation, conserve soil moisture and living organisms, and just as importantly, actually produces equal or increased crop yields (305).

A 2021 study published in *Frontiers in Environmental Science* highlighted the problem pesticide use has had on our soils. One of the co-authors, Nathan Donley, from the Centre for Biological Diversity stated:

> *"Study after study indicates the unchecked use of pesticides across hundreds of millions of acres each year is poisoning the organisms critical to maintaining healthy soils" ... "Yet our regulators have been ignoring the harm to these important ecosystems for decades* (308)*."*

It seems that just as with DDT, short term profits have been prioritized over long-term health, and the clock is now ticking down to 2074. Even if we stop degrading our soils, they may still come back to haunt us as the atmosphere warms. It has been suggested that if we hit 2°C of warning, then the soils will begin to spill some 230 GtC into the air, potentially tipping us into abrupt climate change (306).


“Earthworms are far more valuable than people.”
Paul Watson

*Dear Indy,*

*Let's talk soil. That lovely brown stuff in the garden that we love so much. When we moved into our new farm, our garden was covered in black plastic sheets. They had been laid down to stop excessive weed growth as the farm was empty for over twenty years. A new garden had grown on top of the sheets, and this shows that nature will always find a way. It's not really the planet we are trying to save. It's us! The planet will rebound eventually, and life will go on without us. In fact, the planet might be quite happy to see the back of us, well those of us participating in the global economy anyway.*

*After pulling the black sheets back and in the process, doing my back in, we found that while there was life above the plastic, there wasn't much life underneath. In fact, the soil seemed completely void of life. Where there should have been earthworms a plenty, we found none. This was the same everywhere the sheets were placed.*

*When we finally got around to planting the Habaneros, Carolina Reapers and Trinidadian Scorpions, in the land at the back where no plastic was laid down, as I was tilling the soil, I was confronted with an existential crisis. There were beautiful earthworms every which way I worked. Fortunately, I wasn't using any machinery, so the casualties were minimal, but the sheer numbers of big fat juicy earthworms was incredible. It was so amazing to see them all there but at the same time, it made my job of missing them as I used my pitchfork much harder. It was a nice problem to have.*

*Unfortunately, this isn't the case anymore. Fields all around the world are increasingly not home to worms. It seems the culprit here is not black sheets to prohibit weeds, but the very same chemicals that we put on our food. They seep into the ground and our little worm friends don't much like it either. People, including you, might think worms are gross but they are fantastic little friends to us and without them, we will find growing food becomes a lot harder, if not impossible. In addition to Save the Whale and Save the Tiger campaigns, maybe we should have Save the Worm demonstrations too. If they can thrive, we might be able to as well.*