Gerrit Rietveld Academie

BACHELOR THESIS

The language of trees

by
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Introduction

Listen to Trees

The Great Basin bristlecone pine is found in the western United States
[Source:https://www.bbc.com/news/science-environment-40224991]

The oldest, precisely measured organism living on Earth today remains, for now, a Great Basin Bristlecone pine tree. And trees have more species than there are mammals. However, most people see trees as objects because they live very differently than humans live. In comparison with the Animals Rights Movement of the early 20th century, a declaration of the rights of plants titled "The Dignity Of Living Beings With Regard To Plants" was published in 2008 by the Federal Ethics Committee on Non-Human Biotechnology (ECNH) in Switzerland. The title of chapter 2.2.1 "Pathocentrism" states that “plants count because they are able to experience something in some ways good or bad, and therefore have their own interests.” [1] The condition for an independent positive or negative experience is sentience. An organism which satisfies this prerequisite has its own interests. Are plants, in fact, sentient beings?

In this thesis, one can listen to the language of trees through the extensive research of biologists and forest ecologists, who offer a new perspective for viewing the forest as a collection of intelligent social beings. On the other hand, I will provide examples of Nordic social models as a comparison with forests community. Find the links and connection between Nordic way of life and forests.

Chapter 1

1.1 The Method of Tree Communication

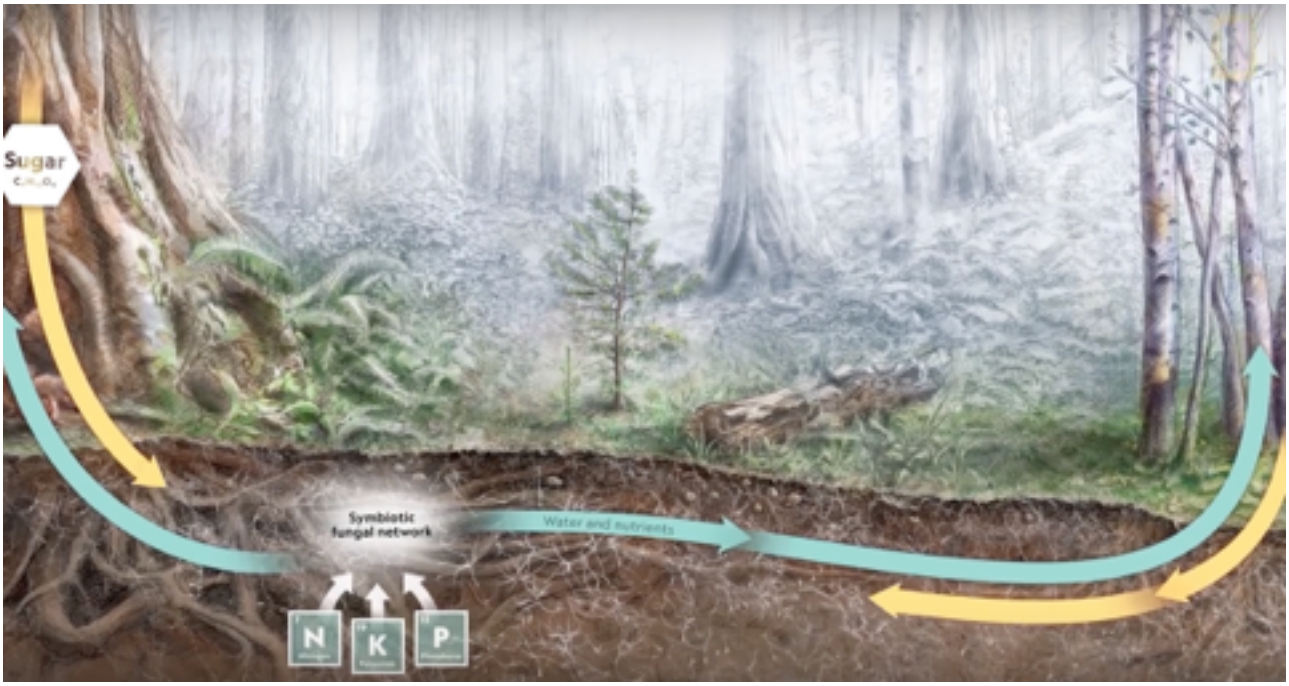
1.1.1 Core Concept

When we walk into forests, we might perceive trees to be isolated, solitary individuals. However, they are capable of communicating with each other due to their special relationship with fungi. Nearly all known plant species have a mutually beneficial relationship with soil fungi called mycorrhizae. The word ‘mycorrhizae’ stems from the Greek words for fungus and root. Mycorrhizae grow a network of small, branching tubes called a mycelium, which extends

throughout the soil, including inside and around tree roots. These tubes allow the fungi to provide the trees with nutrients from soil, like nitrogen and phosphorus. In return, the fungi receive sugars. By plugging into the fungal network, trees can share resources with each other. The system has been nicknamed the Wood Wide Web. [2] [3]

The whole process starts with hub trees, which are the oldest and tallest trees in the forest. Hub trees are also called "mother trees." Hub trees have greater access to sunlight, and through the process of photosynthesis, they end up producing more sugar than they actually need. Underground fungi need sugar to survive, so they exchange sugar, nutrients, and water. Also, trees use this fungal network to supply shaded seedlings with sugars, giving them a better chance of survival. Trees that are sick or dying may dump their resources into the network, which might be used by healthier neighbors. Plants use fungi to send messages to one another, too. If they are attacked, they can release chemical signals through their roots, which can warn their neighbors to raise their defenses.

The symbiotic relationship between trees and fungi was discovered in the early 1900s, but it was not until 1997 that we understood just how deep the underground network goes. Forest ecologist Suzanne Simard and her research team did an experiment in which they infused trees in a forest with a traceable radioactive form of carbon, and later took samples from neighboring trees. It turned out that many nearby trees had the radioactive carbon, as well, proving that plants can send nutrients to each other. In addition, the trees seemingly distributed the nutrients where they were most needed. The research team also created a map by examining the short sequences of DNA of every tree and every fungal individual in a patch of Douglas fir forest. They found that one tree was connected to 47 other trees. Their models also showed that when hub trees were removed, it would cause more connections to be lost than if trees were simply removed randomly. [4] [5]



[Source:https://m.youtube.com/watch?v=7kHZ0a_6TxY]

1.1.2 Forms

Language is what people use to talk to each other. From this perspective, we are the only beings who can use language because the concept is limited to our species. Primarily, we rely on visual and auditory senses for communication. We receive stimulations through sounds and body movements when we talk. Then, the stimulations transform into something meaningful in our brain, fulfilling the aim of "connecting." If the essence of language is making connection with other beings, then we should consider that trees have their own language, and that they are able to communicate with others. In fact, trees have a completely different form of communication: scent. However, trees do not rely exclusively on dispersal in air, they also communicate with each other using chemical signals sent through the fungal networks around their root tips. New bulletins are sent via the roots not only through chemical compounds, but also by means of electrical impulses that travel at the speed of a third of an inch per second. The following illustrates some specific cases for the chemical scent of trees, as a form of communication using signals and messages. And showing the communications of trees that improving the rates of survival.

Ethylene

Four decades ago, scientists noticed something on the African savannah. The giraffes were feeding on umbrella thorn acacias, and the trees were not happy. It took the acacias mere minutes to start pumping toxic substances into their leaves to rid themselves of the large herbivores. The giraffes got the message and moved on to try other trees in the vicinity. Only when they had moved about 100 yards away, they could finally resume their meal. The reason for this behavior is astonishing. The acacia trees that were being eaten had given off a warning gas of ethylene that signaled to neighboring trees of the same species that a crisis was at hand. All the forewarned trees pumped toxins into their leaves to prepare themselves. The giraffes were wise to this game and therefore moved father away to a part of the savannah where they could find trees that were oblivious to what was going on. Ethylene became a successful warning signal for the trees. [6]

Pheromone

In a pine forest, pine trees often go under attack by aphids (insects) that can multiply at an incredible rate. A single aphid could give rise to around 600 million aphids in a year. In order to combat this attack, the trees ask for help by emitting an invisible cloud. The cloud is a strong perfume that attracts ladybirds. The ladybird senses the cloud and knows that there is food there, so it flies to the tree and feeds on the aphids. It is claimed that ladybirds are as sensitive to the cloud emitted by the pine as a shark is to the smell of blood in the sea. [7]

[Source: 22:13 Judi Dench, My Passion for Trees, 2017]

A similar event happens in Africa, where Colophospermum mopane [8] attacked by elephants release alarm pheromone to warn other trees. However, the alarm signals travel through the wind, so occasionally an elephant will learn that it can eat the leaves of the trees upwind to the signaling tree, as these trees do not receive the airborne signal. The rest of the elephants that do not outsmart the tree must move on to eat elsewhere because all the warned trees in the surrounding area repel them with highly acidic leaves.

Tannins and Salicylic acid

Oak trees carry bitter, toxic tannins in their bark and leaves. These toxins either kill chewing insects outright, or affect the leaves' taste to such an extent that instead of being deliciously crunchy, they become biliously bitter. Another example are Willow trees that produce the defensive compound salicylic acid, which works in much the same way as the tannins. Salicylic acid negatively impacts the insects, but the same cannot be said for modern humans. Salicylic acid is a precursor of aspirin, and tea made from willow bark can relieve headaches and bring down fevers. [9]

1.1.3 The Aim of Communication

Language is power, especially nowadays, when social media allows language to spread faster and have more influence on the world. People post on Twitter, Facebook, and Instagram for all kinds of purposes. These posts may showcase lovely dinner dates, new products on the market, or some malicious gossip. There are countless reasons for human communication. But what about trees? From much scientific research, we already know about underground networks in forests. Scientists in the Harz mountains in Germany have discovered that this really is a case of interdependence, and most individual trees of the same species growing in the same stand are connected to each other through their root system.[10-1] It appears that nutrient exchange and helping neighbors in times of need is the unwritten rule among trees, and this supports the idea that forests are super organisms with interconnections much like ant colonies. According to Massimo Maffei from the University of Turin [10-2], plants, including trees, are perfectly capable of distinguishing their own roots from the roots of other species and even from the roots of related individuals. They do create a social network.

Ecosystem

Why are trees such social beings? It goes without saying that an individual tree is not a forest, but many trees together create an ecosystem that moderates extremes of heat and cold, stores a great deal of water, and generates a great deal of humidity. If every tree were looking out only for itself, then a great many of them would never reach old age. Every tree, therefore, is valuable to the community and worth keeping around for as long as possible. The tree communities may even resemble human societies, as there are different levels of membership within the society. According to Peter Wohlleben in "The Hidden Life of Trees," the average tree grows its branches out until it encounters the branch tips of a neighboring tree of the same height. It does not grow any wider because the air and better light in this space are already taken. However, the tree heavily reinforces the branches it has extended, giving the impression that there is quite a shoving match going on up

there. Even so, a pair of true friends is careful right from the outset not to grow overly thick branches in each other's direction. The trees do not want to take anything from each other, so they develop sturdy branches only at the outer edges of their crowns. Such partners are often so tightly connected at the roots that sometimes they even die together, like in the case of Jōmon Sugi, a cryptomeria tree, located on Yakushima, a UNESCO World Heritage Site, in Japan. It is the oldest and largest among the old-growth cryptomeria trees on the island, and it is estimated to be between 7,170 and 7,200 years old. The oldest cryptomeria trees are actually three trees connected to each other, making one body.

The social network of forests is similar to that of human societies in the fact that it also has a dark side. For instance, black walnut trees spread toxic chemicals throughout the network to sabotage their rivals. Some scientists believe that when trees are attacked by animals and send alarm signals, these signals are not actually for their neighbors. Instead, they are for themselves, and are stolen by the neighbors. For many years, there has been a controversial discussion about whether the "thinking system" of the social network of trees is altruistic and intelligent. Vanessa Bursche from RWTH University [11] shed some light on this topic by discovering something amazing about photosynthesis in undisturbed beech forests. Every tree in a forest experiences different growing conditions, and thus, it may be expected that every tree photosynthesizes at a different rate. However, the research results showed that the rate of photosynthesis is the same for all of the trees. It appears that the trees are equalizing differences between the strong and the weak. This equalization is taking place underground through the roots. There is a lively sugar exchange, among other exchanges, happening below the surface. The exchange is similar to the way the social security system operates to ensure that individual members of society do not fall too far behind.

1.1.4 Community Members

Virginia Woolf wrote that "Real life was the common life, not the little separate lives which we live as individuals." [12]

It is now established that the communication network of the forest, comprised of a union of trees, fungi, bacteria, and insects, cannot be separated. The intelligence of the forest, therefore, emerges from many kinds of interlinked clusters of thought. The following section goes more into detail about each member of the forest community, including the individual unique roles in the network.

Trees

The underground world of the forest is still like a mystery. The roots of most trees are shallow, and they spread out very wide. Most people do not know that the roots spread at least as far out as the tree is tall. Roots and twigs have memories of light, gravity, heat, and minerals. The intelligence of trees exists not inside of the body, but in the relationships with other species. Root tips converse with species from across the community of life, but especially with bacteria and fungi. Hence, trees can send nutrition and chemical signals to their neighbors and fellow seedlings. Tree roots are not only associated with fungi and bacteria, as they also connect with other trees. Peter Wohlleben illustrates this connection:

“Douglas firs, which are native to North America but now grow in Central Europe as well, react in much the same way as oaks, but in their case, their roots seem to be super sensitive. In the forest I manage I’ve observed two lightning strikes where not only the tree that was struck died, but another ten Douglas firs within a radius of 50 feet of the strike experienced the same fate. Clearly, the surrounding trees were connected to the victim underground, and that day, instead of life-giving sugar, what they received was a deadly serving of electricity.”
The Hidden Life of Trees, 2017, Chapter 31-7 of 12

It is not just the underground world of trees that play an important role in this communication network. For example, there are plant cells in leaves that smell the air to detect the health of neighbors. Also, trees use airborne odors to attract helpful caterpillar-eating insects. Trees have multiple forms of communication, both underground and above ground.

The Life of Trees

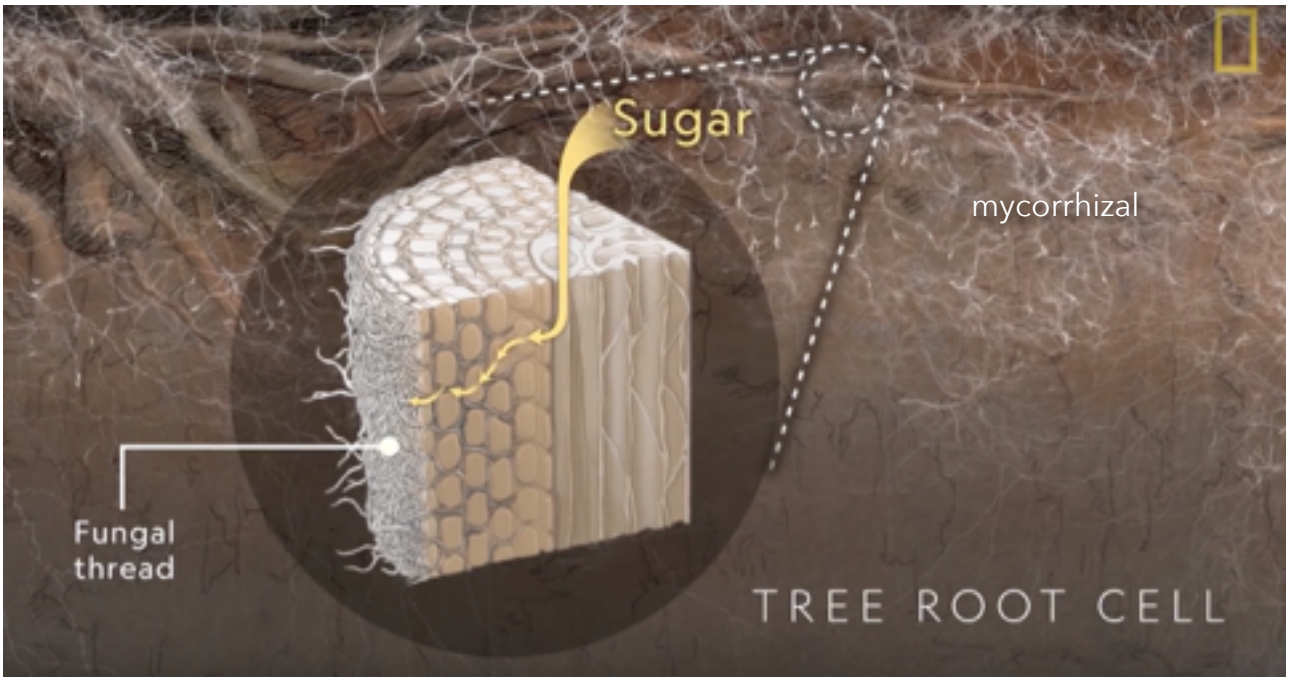
How can we learn from death? The physiological condition of the tree is very different than that of human beings. We rely on our central nervous system to control our mind and actions. If we lose an organ, it might cause a serious injury or death. Trees, on the other hand, can lose 90% of their body and still live thanks to their root system and relationships with other species in the forest. Death is not an ending for trees and forest networks. As trees rot away, dead roots, branches, and logs become focal points for thousands of species in the forest. They do not lose their relationships. At least half of the other beings find food or home in fallen trees. Also, the fallen trees become humus of forest soil. In "The Songs of Trees," David George writes:

“When a being—a person, a tree, a chickadee—full of memory, conversation, and connection dies, the network of life loses a hub of intelligence and life. For those closely linked to the deceased, the loss is acute. An ecological analog of grief unfolds in the forest: for the other creatures that depend on living trees, death ends the relationship that gave them life. The living tree’s partners and foes must all find a new live tree or they will themselves die.”
The Songs of Trees, 2017, Green Ash 18 of 19

David George expresses how forest networks resemble human communities in the aspects of death, loss, and social dependence. To add to that, the death of the hub trees, which are the primary trees that send nutrition to their seedlings, can be compared to the loss of a mother animal that cares for her young.

Fungi

A mycorrhiza is a symbiotic association between a fungus and a plant. These relationships play important roles in plant nutrition, soil biology, and soil chemistry. In a mycorrhizal association, the fungus colonizes the host plant's root tissues, either intracellularly as in arbuscular mycorrhizal fungi (AMF), or extracellularly as in ectomycorrhizal fungi. The mycorrhiza is important for plants because most cannot grow well without it. Mycorrhizal fungi can exchange nutrition and water with host plants while receiving sugar in return. Also, the plant's roots can uptake phosphate for itself and the fungi, which would otherwise be difficult for the fungi to do. A tree that does not associate with mycorrhizal fungi may only grow to a small fraction of its potential height, thus, this relationship is essential for the growth success of plants.



[Source:https://m.youtube.com/watch?v=7kHZ0a_6TxY]

Forest Soil

Can you imagine that a handful of forest soil has more life forms than people on the planet? More specifically, one gram of forest soil has one billion life forms, which is the same quantity as the population of Japan. Also, a mere teaspoonful contains many miles of fungal filaments. All of these organisms work to transform the soil in order to make it more valuable for trees. The most important element of the vegetation in soil is the accumulation of organic matter. The tree leaves represent the most important source of carbon in the soil. The type of vegetation is also an important factor because it affects the soil acidity. For forest soil, everything is useful, whether it is alive or dead. Humus is the dark organic matter that forms in soil when dead plant and animal matter decays. Humus has many nutrients that improve the health of soil, nitrogen being the most important. Soil is the foundation of ecosystem cycling, and it is home to the building blocks of the forest network.

1.1.5 Summary

Returning to the original question, “are plants sentient beings?," evidence shows that plants are, indeed, sentient. Simply the example of hub trees sending nutrition to their seedlings when they need help, just like mothers help and give love to their children, is a strong parallel between the human concept of sentience and that of plants. Trees also help each other by sharing carbon, water, and defense signals in forests. If they were not sensitive to danger and death, or they did not “think” that it is important to help other community members, then they would not behave like that. Overall, plants are sentient beings because forests and trees have advanced network communication systems, which exist and operate in accordance with a collective, social desire for the survival and well-being of the community members.

Chapter 2
Thinking with the Mind of Forests

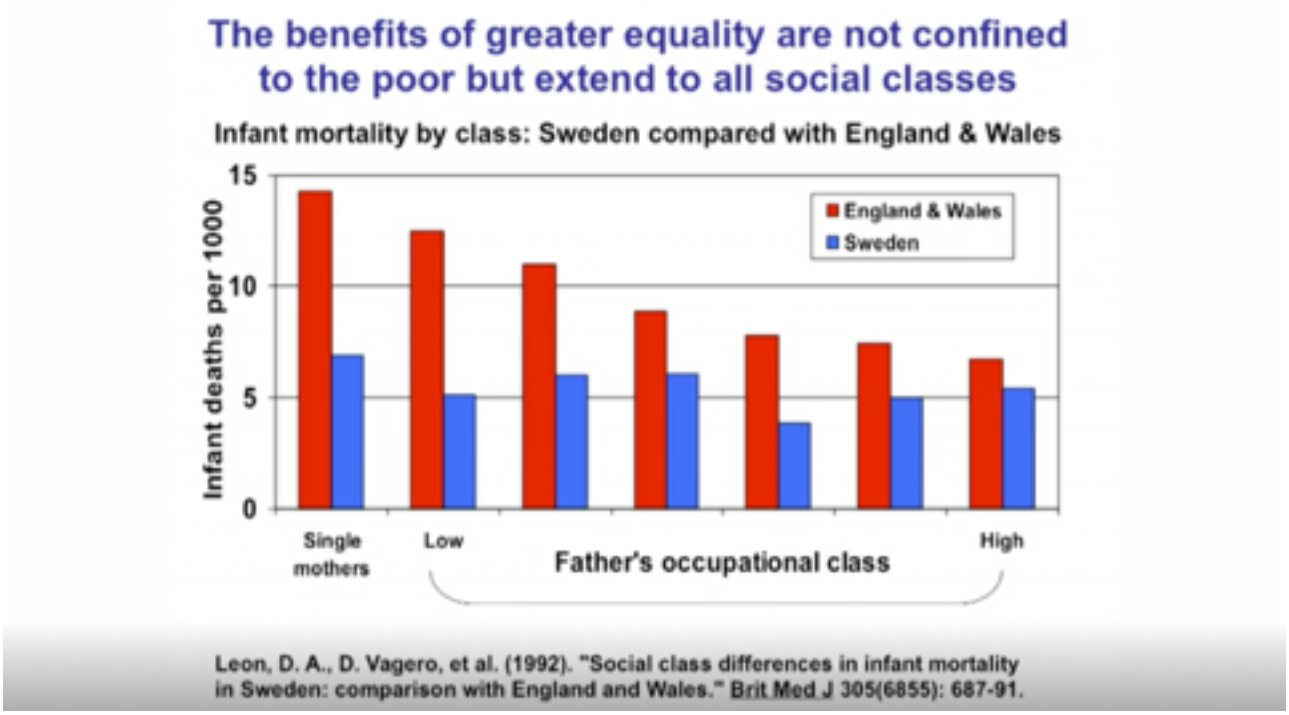
“Every tree is a living person, with speech. Ceibo tree represents all plant life; you cannot listen to “one” tree; there is no one tree living alone.”
Teresa Shiki, The Songs of Trees, 2017, Chapter 1-1

There is something very true in these words spoken by a Shuar woman of the Amazon Rainforest. Members of a forest are interconnected in a way that is comparable to the network of human society. Nowadays, scientific research sheds new light on the mysterious interconnectedness of the forest that indigenous tribes understood. Trees, like human beings, live in a group of socialization. However, the specific way in which they live is very different from that of humans. Trees do not live such mobile lives as humans live, considering that they stay physically in the same spot for their entire lives, which can last much longer than human lives. As a result of this special condition of life, trees have to stand together and establish a strong social network. Life is not easy for trees, as they cannot move freely. Also, when a tree falls down, the tree might hit other trees and injure them. These injuries may take their health or even life. Most of the time, though, trees will look out for each other and try to minimize such injuries. That is why they communicate with their neighbors to prevent attacks from animals or pests. Helping each other is a key point of survival for all beings.

2.1.1 Nordic way of life

The collective mindset of trees can be compared to the Nordic way of life. Nordic countries are famous for prioritizing social welfare. Their social systems help to provide equal living conditions and rights for citizens. In 2019, the World Happiness report showed that Finland is the happiest country in the world, with Denmark, Norway, Iceland, and the Netherlands holding the next top positions. In this report, the top four countries are Nordic countries, which shows how social welfare is connected to the happiness of people. There are also studies showing how economic inequality can actually be very problematic for society. The following is an example from a British social epidemiologist Richard Wilkinson’s TED talk, "How economic inequality harms societies," showing the benefits of wealth equality in Sweden, one of the Nordic countries, along with the negative consequences of wealth inequality in England and Wales. [13]

Some Swedes kindly classified their infant deaths according to the British register of general socioeconomic classification. On this graph, the low social class consists of unskilled manual occupations. Heading to the right, there are skilled manual occupations in the middle, then the junior non-manual, and then the high professional occupations, such as doctors, lawyers, and directors of larger companies. The results show that Sweden does better than England and Wales, regarding infant mortality, all the way across the social hierarchy. The largest gap between Sweden and the other countries exists among the lowest social and economic class. Although, even at the top, there still seems to be some benefit from being in a more economically equal society.



[Source: https://www.ted.com/talks/richard_wilkinson.htmlminute6/]

In addition to increased rates of infant mortality, there are psychosocial effects of economic inequality, such as feelings of superiority and inferiority, being valued and devalued, and respected and disrespected. Such feelings lead to status insecurity, status competition, and more importantly, the consumerism of society. On the other hand, among trees in forests, there is an absence of problematic consumerism and competition. In fact, trees often avoid competition. For example, crown shyness is a phenomenon observed in some tree species, in which the crowns of fully stocked trees do not touch each other, forming a canopy with channel-like gaps. There are many hypotheses for why crown shyness is an adaptive behavior, and research suggests that it might inhibit the spread of leaf-eating insect larvae. Another theory is that crown shyness exists so that trees do not block their neighbors from getting enough sun exposure. If trees have equal life conditions and health in the same forest, these trees as a community would be stronger, and they would have a higher chance of survival and resilience against any kind of disaster.

[The phenomenon of crown shyness. Source: https://i0.wp.com/sci101.news/wp-content/uploads/2019/06/1560135023143.jpg]

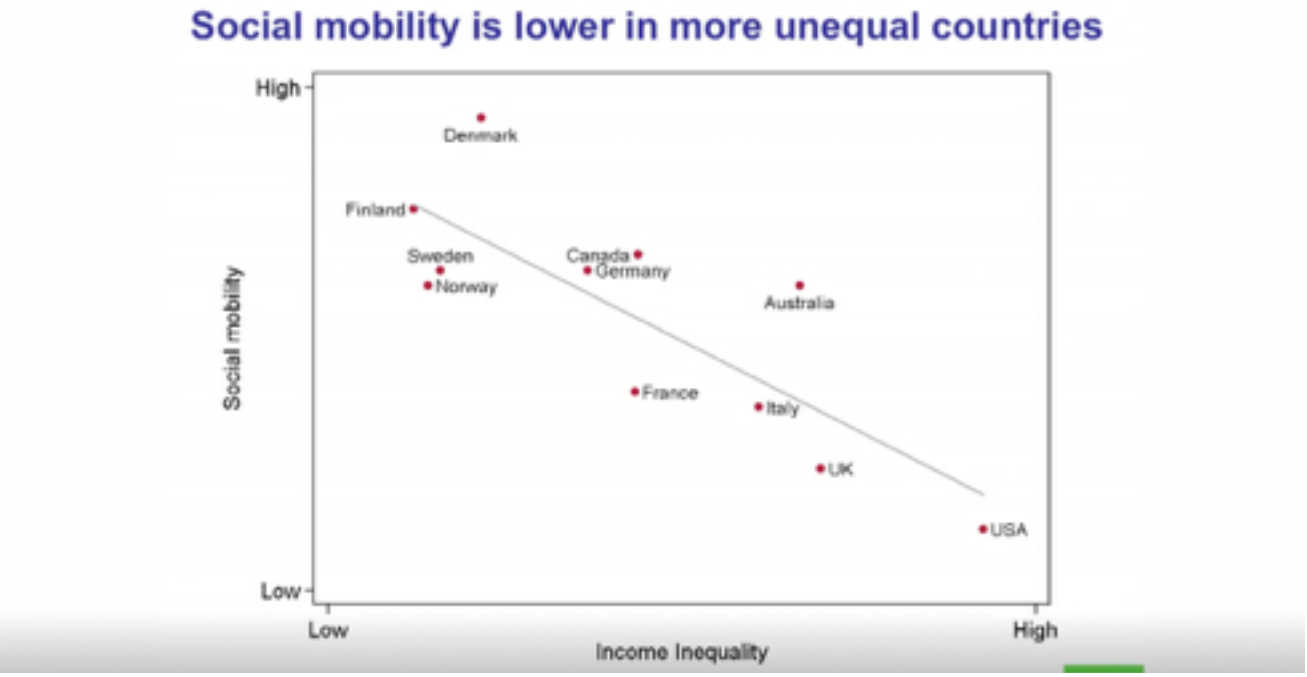
2.1.2 Storage effect and Social welfare

Another mechanism of species coexistence in the forest is the storage effect, which explains how a wide variety of similar species are able to coexist within the same ecological community. In a changing environment, no species can be the best under all conditions. Instead, each species must have a unique response to varying environmental conditions, and a way of buffering against the effects of bad years. Jacob Usinowicz and his team conducted research that shows how the storage effect works in tropical forests, enabling tree species to coexist. The results state:

"On the equator at Yasuni, Ecuador, several hundred tree species flower each month. A harsh weather anomaly in any particular month affects flowering in a small percentage of the species. The timing of harsh anomalies varies among years, and, as a result, species have successful reproductive events largely independently of one another."
Species abundance: Winter restricts innovation,Smithsonian Tropical Research Institute, 2017

The idea of the storage effect is that competing species within the same community have different responses to the changing environment. In some years, species A has better life conditions than species B. But in other years, species B lives better then another, and so on. None of the species are the best, or always thriving, in the same community, and yet, none of the species die out. They have found a way to coexist without a hierarchy of quality of life. The species have equal access to meeting their needs.

Another component to having equal access to quality of life, in the case of human society, is the factor of social mobility, as discussed by Richard Wilkinson in his TED talk. The following graph and commentary depicts the relationship between economic inequality and social mobility.



[Source: https://www.ted.com/talks/richard_wilkinson.htmlminute6/]

"This is social mobility. It's actually a measure of mobility based on income. Basically, it's asking: do rich fathers have rich sons and poor fathers have poor sons, or is there no relationship

between the two? And at the more unequal end, fathers' income is much more important -- in the U.K., USA. And in Scandinavian countries, fathers' income is much less important. There's more social mobility. And as we like to say -- if Americans want to live the American dream, they should go to Denmark."
Richard Wilkinson TED talk 2011

It seems that social welfare in Nordic countries increases social mobility, and thus, it is easier for citizens to have higher quality of life regardless of their lineage. The same thing happens with the storage effect in the forest. Regardless of the species of an individual, all plants have equal opportunity to grow and thrive, especially because there is a sense of social welfare, or looking out for one another in the forest.

2.1.4 Summary

It appears that the Nordic social and economic model is the most similar to that of the forest community, compared to many countries in the world. Key systems of social welfare and wealth equality help take care of citizens, like members of the forest take care of each other. The community mentality ensures that there is effective communication and distribution of resources among all members. The success of this model evidently leads to increased stability and happiness within the community. There is a common saying that "teamwork makes the dream work," and this proves to be true when looking at the forest and Nordic communities. Other countries may not interested in, or able to, follow suit due to varied complex reasons. However, coexistence should be the goal for all beings on this planet, as we run into serious problems without it. The forest would not exist as we know it without its natural harmony of coexistence.

Conclusion

Why do trees share resources and form alliances with trees of other species? Doesn't the law of natural selection suggest they should be competing? Ecologist Suzanne Simard contests that “actually, it doesn’t make evolutionary sense for trees to behave like resource-grabbing individualists. They live longest and reproduce most often in a healthy stable forest. That’s why they’ve evolved to help their neighbors.” As Simard said, the wisdom of the forest is all about “cooperation." [14] Prioritizing the greater good of the whole community gives cooperating networks evolutionary advantages over competing individuals. As we see in the Nordic welfare model that refers to the welfare policies of the Nordic countries, which also tie into their labor market policies. The Nordic model of welfare is distinguished from other types of welfare states by its emphasis on maximizing labor force participation, promoting gender equality, egalitarian and extensive benefit levels. [15] A universal nature of the welfare provision in order to safeguard individualism by providing protection for vulnerable individuals and groups in society and maximizing public participation in social decision-making. [16] From the concept of the Nordic welfare model linked to forest community. It’s an important thing we could learn from both of social models.

On the other hand, the intelligence of the forest is often underestimated by humanity, hence we do not see how we are similar and how we can learn from the trees. An example of this similarity can be found in the mother tree. Most of us have experienced having a mother who takes care of us as a child. The strong love between a mother and child exists in the forest just as much as it does anywhere else. We should consider that trees are not much different from animals in this regard. For this reason, trees and plants should have their own rights to life and being protected in our societies. Unfortunately, this is not the case, as the tropics lost 12 million hectares of tree cover in 2018, the fourth-highest annual loss since record-keeping began in 2001. Of greatest concern is the disappearance of 3.6 million hectares of primary rainforest, an area the size of Belgium. How important is it to us to protect forests? We are facing serious issues of climate change, and a tree is an example of a natural climate solution. The foundation of all climate solutions depends on the continuing function of nature. The world’s intact forests soak up a quarter of all humanity’s carbon emissions each year. Nature is a tool we can use to repair our broken climate. First, we need to stop destroying the forests, while also sharing the knowledge of trees living in the world. People should wake up and help the ecosystem bounce back. The first step is to understand the life of a tree.

Bibliography

[1] “The Dignity Of Living Beings With Regard To Plants” , The Federal Ethics Committee on Non-Human Biotechnology (ECNH), 22 Apr. 2008, Web <https://reurl.cc/e5Da0j>

[2] “How trees secretly talk to each other” BBC News, 2018, Web <https://www.youtube.com/watch?v=yWOqeyPIVRo>

[3] “From Barren Land to Tropical Forest - Investigating Fungi: The Wood-Wide Web” The Open University, 2011, Web <https://www.youtube.com/watch?v=LcTQrUQOXdE>

[4] “How trees talk to each other” Suzanne Simard2016, TED, Web <https://www.ted.com/talks/suzanne_simard_how_trees_talk_to_each_other>

[5] ”How Trees Secretly Talk to Each Other in the Forest” National Geographic, 2018, Web<https://www.youtube.com/watch?v=7kHZ0a_6TxY>

[6] “The Songs of Trees: Stories from Nature's Great Connectors” David George, Publisher Viking ,April 4, 2017

[7] “Judi Dench-My Passion for Trees“ Harvey Lilley, 2017, Web <https://www.imdb.com/title/tt7775394/>

[8] “The Elephant and the Mopane Tree” Treelogy, 2017,web <https://medium.com/@treelogyworld/the-elephant-and-the-mopane-tree-a5402c6af702>

[9]“Tree : A life story” David Suzuki, Wayne Grady, Greystone Books; First Trade Paper edition, February 22, 2007

[10-1][10-2] “The Hidden Life of Trees: What They Feel, How They Communicate—Discoveries from A Secret World” Peter Wohlleben , Greystone Books; First English Edition edition, September 13, 2016

[11] “The forest unseen”, David George Haskell, Penguin Books, March 15, 2012

[12] “Virginia Woolf Biography” 2017,web <https://www.biography.com/writer/virginia-woolf>

[13] “How economic inequality harms societies”TED, 2011, Web <https://www.ted.com/talks/richard_wilkinson?language=zh-tw>

[14] “Nature's internet: how trees talk to each other in a healthy forest | Suzanne Simard | TEDxSeattle” 2017,Web <https://m.youtube.com/watch?v=breDQqrkikM>

[15] Esping-Andersen, G. (1991). The three worlds of welfare capitalism. Princeton, NJ: Princeton University Press. p. 228.

[16] The Nordic Council. "About the Nordic welfare model”, Norden. Retrieved, 2 April 2014