Ronan Taylor

28 October 2021

Biospheric Restoration Systems

Plants in the Past

In the 1600s when the Europeans first arrived in the New World en masse, accompanying them were a myriad of diseases such as smallpox, malaria, influenza, cholera and even the common cold. None of which the millions of indigenous Americans at the time had any resistance to. The high transmissibility of these diseases combined with a lack of any natural immunity enabled them to spread like wildfire across the continent, cities were abandoned, farmland was left unattended, controlled burns stopped and nature reclaimed the land. Over the next few decades forests, wetlands and grasslands returned to developed areas and in doing so, the land stopped functioning as a net source of carbon and instead became a net carbon sink. (Dull et al.)

The amount of area that was reclaimed is believed to have been roughly the size of France and the sequestered co2 had an incredible impact on the climate initiating what climate scientists and environmental historians call the little ice age, a climatic anomaly that occurred from the 17^{th} to 19^{th} centuries that altered the global climate to a cooler state. While the cause of the little ice age was fundamentally tragic, the lessons it has given us are imperative for us to understand the solutions to the challenges we face today. Plants can help us fight what is possibly the greatest threat humanity has ever faced.

The Current Situation

The state of forests in the Americas currently, is drastically worse than prior to the little ice age, with the overwhelming majority having become even greater net sources of carbon than at any other point in history. The Amazon for example, once one of the Earth's greatest carbon sinks, capable of storing more than 3x the emissions of the UK since the 1700s, has now become a net emitter. To make matters worse, many of these forests that have turned to net emitters, were already highly degraded by industrial activities, logging and agricultural activity over the course of the last three hundred years, losing old growth and biodiversity. This degradation has significantly reduced these forests' ability to sequester carbon.

The climate crisis and the destruction of forests has provided both the need and opportunity to restore these vital carbon sinks. Looking at the facts, we can see that an area the size of France was enough to initiate a global cooling event, we can also see that the overwhelming majority of land on Earth currently needs and would greatly benefit from environmental restoration. This means large scale reforestation is desperately needed in order to combat the climate crisis. (Sheil et al.) (Cerasoli et al.)

Of course, while large scale reforestation could potentially turn the tide on the climate crisis, there are a number of factors holding it back. Firstly, the world is heating faster than normal tree growth rates. This presents a major problem due to the fact that as many as one in three tree species is threatened with extinction from the climate crisis. (*State of the World's Trees*) This is made worse by the fact that old growth forest is the most effective at sequestering carbon, most reforestation methods need at least half a century, but more often than not hundreds of years before they can produce anything resembling old growth.

Most reforestation methods are not only insufficiently fast enough to create effective carbon sinks, but also fail to replicate nature in any optimal way. Many tree plantings often only plant one species in an attempt to create a forest, outside of that absurdly small number, few reforestation projects plant numbers of species outside of single digits. This is problematic as competition between tree species forces many to grow bigger to capture more sunlight and as result, store more carbon, biodiverse forests can store over twice as much carbon as a monoculture. Monocultures are also significantly more vulnerable to blights, droughts, rising temperatures and numerous other factors that could easily wipe them out, factors that climate change is dramatically multiplying. A monoculture is a forest doomed to collapse. (Baltodano et al.)

Monocultures are also horrendous at maintaining biodiversity. For example, many insects have developed commensalistic and mutualistic relationships with a specific species of tree, the most common of these are bees that have specialized in pollinating flowers from one species of tree exclusively. In these relationships, if the plant goes extinct, so does the pollinator and vice versa. In an age of rapid declines in insect populations, reforestation is a must. Of course these interactions are not limited to insects. Many other animals are reliant on biodiverse forests to maintain their livelihoods; many birds and other animals will eat seeds and fruits that trees provide, the outer layer of the seed provides the birds with an abundance of nutrients and the interior layer of the seed will pass from the birds gut to be deposited in the ground far from the parent seed and, with any luck, the seed will develop into a new tree. Human activity has greatly modified the composition of species in forests and this in turn has no doubt degraded biodiversity wherever it has occurred. A biodiverse forest is an essential component to a biodiverse ecosystem, and a biodiverse ecosystem is an ecosystem that is far more resilient to environmental changes. A forest that lacks resistance to environmental changes is likely to collapse and release any subsequent carbon it initially sequestered - further spinning climate change out of control. (Liu et al.)

The Miyawaki Method

Given the limited time and the drawbacks of most reforestation methods, there are a few reforestation methods that could be effective in the face of the climate crisis. The most notable being the Miyawaki method, named after Japanese botanist Akira Miyawaki, who first pioneered the method in the nineties. In his youth, Miyawaki wandered the forests that surrounded shinto shrines in Japan. These forests are considered sacred in Japan, often called Chinju-no-mori, meaning forests where the gods dwell. Due to their spiritual nature, The forests that surround these shrines were never cut, some of these forests have stood without human interference for over 800 years. This allowed Miyawaki to have insight into the native composition and structure of Japanese forests. He later studied potential native vegetation (PNV), a concept utilized to determine what vegetation would be present in an area without human constraints, it examines multiple environmental constraints and paleo-botanical data to draw it’s conclusions. (Hengl et al.)

He used this information to develop what is now known as the Miyawaki method, by replicating the compositions and structures of old growth forests in plantings, Miyawaki soon discovered the planted forests, whose composition was based on old growth forests, grew faster than normal plantings. Later he tested the soil around the old growth sites he was studying and determined several key soil characteristics that were unique to the old growth forests and replicated them in his plantings, this enabled the trees to grow at an unprecedented rate, and with this the Miyawaki method was born.

The method is possibly the most powerful reforestation method ever created and overcomes the weaknesses of other reforestation methods, it ensures biodiversity and can effectively replicate pre human conditions. It also enables extremely rapid growth, with most reforestation methods seeing an average of 20cm worth of growth per year, compared to an average of 110cm worth of growth per year with the Miyawaki method. The method has been successfully utilized thousands of times, in temperate, tropical and arid environments on multiple continents. (Miyawaki) (Schirone et al.)

The method works by first assessing the potential natural vegetation of the area, the most common tree species are identified and they compose roughly 50% of the forest. of the reforestation site and then assess the soil quality of the site. Trees will need to be categorized by height. Once seeds are acquired the plants are raised for 6 months in controlled conditions, once the saplings have sprouted 2 or 3 leaves, they are denied 60% of the normal amount of sunlight through a mesh for 2 months and then the mesh is switched out to deny the saplings 40% light for another two months. After that period the saplings are ready to be planted, before that any adjustments that need to be made to the soil will have to be made, this could include the addition of organic fertilizers, perforators and aerators. Flags should be placed for each tree to be planted, each flag should be color-coded to represent it's height, once planting areas are completely selected the forest can be planted. The forest needs maintenance for the first 6 months, plants should be watered and de weeded. However, once the trees shed their first leaves, there is no longer any need to manage them and the forest should be left to grow, within 10 years it should resemble old growth. (Miyawaki)

Incorporating New Technologies

The Miyawaki method however has one downside, every sapling has to be raised individually in specific conditions. Given the large amount of saplings required per acre, a large-scale planting isn't feasible with this method under normal circumstances, this drawback has limited the size of Miyawaki Projects to mostly a few acres. Given that millions of acres need to be reforested, this is woefully inadequate. We propose that raising the saplings in controlled agricultural environments and container farms, would enable us to overcome the method's limitation and produce forests at an unprecedented rate & scale with the Miyawaki method. Controlled agricultural environments can grow significantly more saplings per square meter than a traditional nursery enabling us to utilize this method on a scale never before possible. This technology should also help overcome many challenges tree nurseries face in the wake of climate change, such as sudden heat waves or cold fronts that are especially deadly towards saplings.

Using the past to save the Future

Our project will incorporate many species frequently neglected in PNV studies, in particular ecological anachronisms. Ecological anachronisms are adaptations or behaviors in organisms that are the remnants of relationships with organisms that are now extinct, specifically megafauna, animals such as gomphotheres, giant ground sloths and mammoths. These organisms were hunted to extinction across the continents by early humans and the ecosystems have never truly recovered since. If an ecosystem is a puzzle, these are missing pieces, one way to see this is through anachronisms. Some anachronisms are like the Komodo Dragon, animals who used to have a range so big it covered most of Australia and it's islands to the north, when humans hunted it's prey to extinction. Komodo dragons are now restricted to a few small islands subsisting off of game animals introduced by humans. (Hocknull et al.)

For the purposes of determining PNV, we need to look at botanical anachronisms. These are plants that once formed mutualistic relationships with extinct megafauna, these plants are often defined by large fruits that would entice the megafauna to eat them and much like modern birds pass the seed through their gut, propagating the species and providing the mammal with a tasty treat. However with the megafauna's extinction at the hands of early humans, these species have barely clung onto survival, carrying on either through secondary dispensers or human cultivation. For example persimmon trees in North America we're frequented by mastodons who dispersed their seeds far and wide, but upon their extinction, persimmon numbers were reduced drastically with only raccoon and opossums dispersing the seeds. Avocados are another example, once dispersed by sloths and toxodon throughout the neotropics and southern North America, this species only survived through the cultivation of it through indigenous peoples. (Janzen and Martin)

These anachronisms can be found throughout the world, and are criminally underlooked when determining PNV, These anachronisms should be included in the methodology in order to maximize biodiversity. This could also prove ecologically beneficial as biotech advances more and more de extinction projects will become viable, these anachronisms were an import part of the lives of many megafauna and if de extinction research proves successful, with this method we will have produced a habitat, easy for them to re transition to.

Our project hopes to combine the power of the Miyawaki method and container farming technology to restore forests as quickly as possible on an unprecedented scale and as close to a pre human state as possible. If we prove successful, we will have developed an extraordinarily powerful tool to combat the climate crisis.

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