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Study of Miyawaki Forest Method in Reducing Co_2 Emission from Concrete Block Production Industry

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Abstract
Climate change is one of the major issues which the world is facing right now caused by the emission of harmful Greenhouse gases such as carbon dioxide(CO2), chlorofluorocarbon(CFC), methane(CH4), etc. These harmful gases are mainly generated from industrial activities, and from other anthropogenic activities. And this leads to the increasing rate of carbon dioxide which will in turn leads to global warming. So it is very important to determine the amount of carbon dioxide produced into the atmosphere. In past years many methods and technologies have been introduced for reducing the rate of carbon dioxide. But studies on natural methods for reducing CO2 emissions are limited. Miyawaki forest is one such method that involves planting trees per square meter. This will reduce the temperature, air and noise pollution, etc. This project focuses on studying about Miyawaki forest method for reducing CO2 emissions from industries. For the present study different industries located in Trivandrum, Kerala will be considered. Finally, a cement concrete production industry was selected for this project which is located in an urban area.
Keywords: *1. Miyawaki, 2. Greenhouse gas, 3. Concrete, 4. Industry.*

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I. I INTRODUCTION

1.1 Miyawaki Forest / Miyawaki Method

Miyawaki is a technique pioneered by Japanese botanist Akira Miyawaki, that helps build dense, native forests. The approach is supposed to ensure that plant growth is 10 times faster and the resulting plantation is 30 times denser than usual. It involves planting dozens of native species in the same area and becomes maintenance-free after the first three years.

1.2 Miyawaki Process

- The native trees of the region are identified and divided into four layers — shrub, sub-tree, tree, and canopy.
- The quality of soil is analyzed and biomass

- which would help enhance the perforation capacity, water retention capacity, and nutrients in it, is mixed with it.
- A mound is built with the soil and the seeds are planted at a very high density — three to five saplings per square meter.

The ground is covered with a thick layer of mulch.

Step 1: Determine the soil texture and quantify biomass

Soil texture helps determine water holding capacity, water infiltration, root perforation capacity, nutrient retention, and erodibility. Check if the texture is sandy, loamy, or clayey. Perforator materials help to improve perforation and allow roots to grow quickly. For this, we can use biomass that is spongy and dry in nature. The husk is a by-product and is easily available at grain mills and animal feed stores. Other options include Rice husk, wheat husk, corn husk (chipped), or groundnut shells (chipped).
Water retainer helps soil retain more moisture and water, as compared to its natural water retention capacity. Natural materials such as coco-peat or dry sugarcane stalk can be used. A good test is to dip the material into the water for some time, take it out and squeeze. If water oozes out during squeezing, then the material can be used as a water retainer.

Step 2: Select tree species for plantation

Make a database of all native species of your area. Identify its type (Evergreen, Deciduous, or Perennial), advantages, maximum height, and assign layer. Check the native species sapling's availability in the nursery, their age, and sapling height. The ideal height is 60 to 80 centimeters. Major species: Choose five different species to be the major forest species; these should be the species that you commonly find in your area. This will constitute 40-50 percent of the number of trees in the forest. Supporting species – other common species of the area will constitute 25-40 percent, and minor native species will make up the rest. Select tree species for plantation shown in fig.4

Sample Database							Sample Plant Order List			
Sl. No.	Botanical Name	Common Name in Local Language	Common English Name	Type	Advantage		Ht. (Mtrs)	Layer	Availability	%
					1	2				
Ex 1	Azadi-rachta indica	Turakevu	Neem	Evergreen	Medicinal	_	25	Tree	Yes	8
Ex 2	Tectona grandis	Sagavani	Teak	Deciduous	Timber	_	40	Canopy	Yes	3
Ex 4	Punica grana-tum	Daalimbe	Pome-granate	Perennial	Fruit	Birds	8	Sub Tree	Yes	2
Ex 5	Jasmine sambac	Dundu-Mallige	Jasmin	Evergreen	Flower	_	3	Shrub	Yes	2

Step 3: Design the forest

Master Plan: Identify the exact area for afforestation to procure materials and execute the project. The minimum width of the project area should be 3 meters, but 4 meters is recommended.

Watering Plan: The water pipeline layout may need to be designed by an architect, based on the daily water requirement for the area, backed by borewells and overhead tanks. The forest should be watered regularly for the first 2-3 years.

Planning Project Execution: We also need to identify spaces such as the material/sapling/equipment storage areas, site offices, and resting areas for laborers. There should also be approach roads to the afforestation area for earthmover access, and to the materials/saplings storage areas for truck access, if the project area is large.

Step 4: Preparing the area

Site inspection: Visit the site to determine the feasibility and scope of the project. Take pictures of the site, and confirm the availability of fencing, maintenance staff, running water, and sunlight. The site should get sunlight for a minimum of 8-9 hours a day. No pipes/drains/wires or debris should be present in the area.

Removing debris and weeds: Weeds take away the nutrition of the soil and also restrict the movement of materials and people. Hence they should be cleaned either manually or using a JCB/John Deere Tractor if the area is huge. Ensure that the pulled-out weeds are disposed of away from the site; else they may re-grow.

Watering facility installation: There should be a main line with watering outlets for hoses, which can reach the entire area of the forest. Watering should be done every day manually using a hosepipe with a shower and not by drip irrigation, sprinklers, etc. The requirement is around 5 liters/sq meter per day.

Physical demarcation of areas: The areas should be marked (with limestone powder or wooden peg/rope) before earthwork starts. Ensure that the marking of areas matches 100 percent with the master plan.

Making approach roads to marked areas: Clear weed growth, big stones, and boulders. The path could be of any material (soil, sand, gravel, tar, etc.), but trucks/tractors should be able to use it.

Mound identification: The forests are usually created on 100 sq meter mounds, and each of these needs a serial number in the order in which they will be created. Only after one mound is created and a plantation completed on it, can the next mound be created.

Step 5: Plant the trees!

Mixing materials: Perforator, water retainer, and fertilizer, all without clumps, should be mixed. They should be mixed in the exact ratio as was decided initially, for each mound.

Preparing the ground for plantation: Each forest is created on a 100 sqm mound. Using an earthmover machine, first dig the earth to a depth of 1 meter on 100 sqm of land. Put half the earth back into the pit and spread it uniformly. This is to make the soil loose. Mix with the soil half the biomass prepared in the previous step. Then put the remaining soil back into the pit and spread it uniformly. Now mix the remaining biomass with this soil evenly. Afterward, shape the soil into a mound. In the Miyawaki method, all saplings will be planted together on a mound, unlike conventional plantations where individual pits are dug up for each sapling.

Selecting trees for plantation: Place plants on the mound to create a multi-layered, natural forest. Try to group plants that grow into different layers – shrub, subtree, tree, and canopy – in each sqm. Try not to place two trees of the same kind next to each other; also, don't follow a pattern while planting the trees. Try to maintain a distance of 60 cm between saplings. The goal is to have a random, dense plantation of native tree species.

Plantation: To plant the tree, dig a small pit on the mound with a trowel, remove the root bag in which the plant was growing, and gently place the plant in the pit. Level the soil outside gently around the stem of the plant, but do not press or compact the soil. There should not be more than 8-10 people on a mound at a time, since the idea is to plant on loose, aerated soil.

Support the plants with sticks: Saplings need support during the initial months so that they don't droop or bend. Insert support sticks into the soil close to the plant, without damaging the roots of the plant. For plants shorter than 1 meter, use 1 meter-long bamboo sticks. For taller plants, use slightly thicker 2 - 2.5 meter-long bamboo sticks. Tie the sticks to the plant stems using thin jute strings. Support sticks will be needed for at least every alternate plant.

Mulching: Mulch should be evenly laid out on the soil, in a 5 - 7 inch layer. To ensure that the mulch stays on the ground and does not fly around, it should be tied down with jute ropes. For this, bamboo pegs should be nailed at the periphery of the forest. Tie the pegs to each other with rope, pressing down on the mulch. There should be 30 pegs, each around 2 ft long, around every 100 sqm mound.

First watering: The first time, the forest should be watered for an hour. The minimum water requirement is 5 liters per sqm or 500 liters per 100 sqm mound.

Step 6: Look after the forest for three years

Monitoring: The forest should be monitored once in 1-2 months, to check if the targets have been achieved and if any changes should be made to improve results. This should be done in the first 8-12 months. Count the number of saplings that have survived, and record the data. The growth of selected species should also be monitored.

Maintenance: Water the forest with a hose pipe once a day. Keep the forest weed-free for the first 2-3 years. Once the forest starts growing, weed growth will stop. Ensure that the plants stay straight, are not buried under the mulch, and are only loosely tied to the support stick. Keep the forest clean, and free of plastic, paper, etc. Maintain a proper drainage system so that water does not get accumulated anywhere in the forest. Do not build bunds in the forest, as accumulated water can kill plant roots. The mortality rate of plants is usually 2-5 percent. Mortality is to be checked only after 3-4 months of planting. Do not use any chemicals like pesticides or inorganic fertilizers. If you notice pests, leave them undisturbed. The forest will slowly build its mechanism to keep itself healthy. Mulching should be maintained for at least one year. The soil should be re-mulched with time since dry soil is detrimental to forest health. Also, never remove organic matter like fallen leaves from the forest floor, as it will kill good soil microbes. As the tree grows taller, longer support sticks may be needed so that the tree shoot does not bend and become weak. Never cut or prune the forest as it could make the forest weaker. Process Miyawaki method shown in fig.5

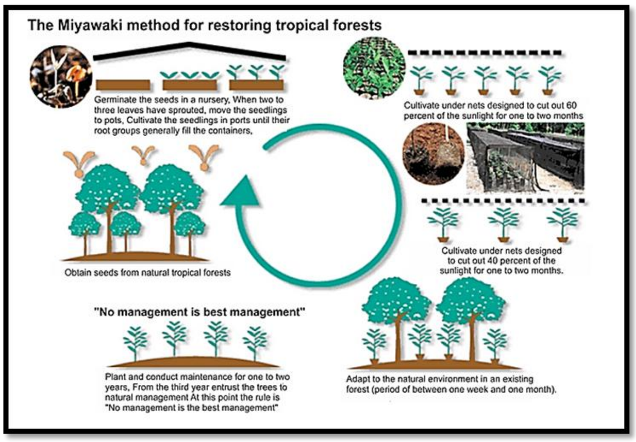

Fig.5 Process of Miyawaki method

It has revolutionized the concept of urban afforestation by turning backyards into mini-forests. This method includes planting trees (only native species) as close as possible in the same area which not only saves space, but the planted saplings also support each other in growth and block sunlight from reaching the ground, thereby preventing the growth of weed. The saplings become maintenance-free (self-sustainable) after the first three years. The approach is supposed to ensure that plant growth is 10 times faster and the resulting plantation is 30 times denser than usual. Miyawaki method helps to create a forest in just 20 to 30 years, while conventional methods take anywhere between 200 to 300 years.

1.3 Selection of Industry

For the present study, a site was selected from Trivandrum district, Kerala is **Regional Nirmithi Kendra – Concrete block production unit**. The site was chosen in such a way that the rate of carbon emission is more. Also to know the difference in carbon emission before and after implementing Miyawaki forest in that critical area.

The total area of Industry = 1 acre 17.960 cent

Available area for project = 2750 sqm.

The site was represented as a critical area because the considered industry was having hollow block production unit. Therefore the usage of cement content will be higher so the emission of carbon will also be higher.

The site was chosen because the selected industry was located in an urban area surrounded by many residential buildings in addition to that a hollow brick production unit is also functioning. Therefore the pollutants, as well as carbon emitted, will be higher in this location compared to normally functioning industries. A large number of hollow bricks made of cement are made per day. Due to the high usage of cement content, the emission of carbon will be much higher.

After collecting the necessary data, such as how much hollow bricks are produced per day, total cement content used per day, etc.. Using formulas from past research, the carbon emitted will be determined. After finding the total carbon emission at the site, the soil condition will be checked for further implementation of the Miyawaki forest.
The carbon emission will be determined after implementing the Miyawaki forest. The difference in carbon emission can be found before and after implementing the Miyawaki forest to study the effectiveness of the method in the reduction of carbon.
The data collected from the industry shows that there are mainly two machines used;

- Concrete mixer machine
- Concrete block-making machine
- 1.5 HP Motor pump etc.

These are working with electricity and hydraulic power. So that the CO_2 emission from the machinery is not indirect.

1.4 Implementation of Miyawaki forest
1.4.1 List of Trees – Industrial regions

In industrial areas, trees that may reduce noise and air pollution and act as a barrier against dust should be used. Every piece of vacant land in these places needs to be planted with trees and other vegetation**.** As per the research of the **Kerala Bio-diversity Board**, the list of trees that can be used in industrial regions is given below;

Sl no.	Scientific name	English name
1.	*Artocarpus heterophyllus*	Jackfruit Tree
2.	*Mangifera indica*	Mango Tree
3.	*Hopea parviflora*	Iron wood of Malabar
4.	*Morinda coreia*	Indian Mulberry
5.	*Grewia tiliifolia*	Dhaman
6.	*Lagerstroemia reginae*	Queen's crepe-myrtle
7.	*Ailanthus triphysa*	Maharukh Tree
8.	*Saraca asoca*	Ashoka Tree
9.	*Garcinia gummi-gutta*	Malabar Tamarind
10.	*Butea monosperma*	Flame-of-the-Forest
11.	*Careya arborea*	Patana oak (Wild guava)
12.	*Pongamia pinnata*	Pongamia Tree
13.	*Syzygium cumini*	Jambul
14.	*Ficus religiosa*	Peepal tree
15.	*Ficus benghalensis*	Banyan tree
16.	*Azadirachta indica*	Neem
17.	*Mimusops elengi*	Spanish cherry (Medlar)

1.4.2 Trees by Layers

1.4.2.1 Canopy layer

This is the top layer of the Miyawaki forest. This layer contains trees above 40 feet in height.
A list of canopy layer trees is given below;

Sl no.	Name of Trees – Canopy layer
1.	Sacred fig
2.	Wild jack
3.	Black varnish tree
4.	Indian rosewood
5.	Red Silk cotton tree
6.	Blackboard tree, Devil's tree
7.	Bullet wood
8.	Cinnamon
9.	White teak
10.	Strychnine tree
11.	Malamanchadi
12.	Yellow teak
13.	Mango tree
14.	Coral wood tree
15.	Indian Coral, Tiger's claw, Sunshine tree
16.	Fragrant ashok
17.	Indian Gooseberry
18.	Tree of heaven
19.	Banyan tree
20.	Jack fruit tree

1.4.2.2 Tree layer

This layer contains trees about 20 - 40 feet in height.

Sl no.	Name of Trees – Tree layer
1.	Kanara nutmeg
2.	Malabar ebony,Wild Mangosteen
3.	Fragrant padre tree
4.	Indian tulip tree
5.	Beach Calophyllum
6.	Red sandalwood
7.	Rambutan
8.	Rudraksham
9.	Chikoo/Sapota
10.	Bread fruit
11.	Indian laurel
12.	Bastard myrobalan
13.	Panama tree
14.	Indian beech
15.	Tamarind
16.	White cedar
17.	White dammar
18.	Malabar kino
19.	Vediplavu
20.	Karinthuvara

1.4.2.3 Sub–tree layer

This layer contains trees about 6 - 12 feet in height.

Sl no.	Name of Trees – Sub Tree layer
1.	Star fruit
2.	Custard apple
3.	Illipe butter tree
4.	Powderpuff mangrove
5.	Vegetable hummingbird
6.	Sage leaved alangium
7.	Wax apple, Java apple
8.	White silk cotton
9.	Cluster fig
10.	Avocado
11.	Dhaman
12.	Sandalwood tree
13.	Cacao tree
14.	Dyer’s oleander
15.	Burma Ironwood
16.	Coffee
17.	Mangosteen oil tree
18.	Indian rock fig
19.	Cashew nut
20.	Kattuchamba
21.	Drumstick
22.	Neermulli
23.	Sea Hibiscus
24.	Garari
25.	Pong Pong Tree

1.4.2.4 Shrub layer

This layer contains trees about 6 feet in height.

Sl no.	Name of Trees – Shrub layer
1.	Malabar nut
2.	Candle bush
3.	Water hemp
4.	Oleander
5.	China rose
6.	Lemon
7.	Turkey berry
8.	Confederate rose
9.	East Indian screw tree
10.	Cape jasmine
11.	Citron
12.	Lemon basil
13.	Holy basil
14.	Small knotweed
15.	Horse wood, maggot killer
16.	Chinese chaste tree
17.	Curry tree
18.	Ironwood tree
19.	Rattle weed
20.	Indian leadwort
21.	Ceylon leadwort
22.	Pagoda flower
23.	Mountain sweet thorn
24.	Pomelo

25.	Golden trumpet vine
26.	Firecracker plant
27.	Camphor Basil

II. RESULTS AND DISCUSSIONS

2.1 GENERAL

The results obtained for the present study are discussed in this section;

2.2 OBSERVATION

From the first phase of this project, as per the calculation, the average CO_2 emission from the production of the concrete block of the selected industry is approx. 0.004 kiloton per day.

Chemical composition of wood

The main component of the cell walls of trees is Cellulose $(C_6H_{10}O_5)_n$.
Carbon – 50%
Oxygen – 42%
Hydrogen – 6%
Nitrogen – 1%
Mineral matter - 1%

2.3 CALCULATION

CO_2 Absorbs

1000 kg of tree = 100 % humidity
Therefore, Water content = 500 kg
Dry mass = 500 kg
47.5 % of Dry mass is Carbon = 500 x (47.5/100)
Dry mass of Carbon = 237.5 kg
As per the Molar mass ratios,
The molar mass of carbon = 12
The molar mass of oxygen = 16
Atomic mass of CO_2 = 12+(16x2)
=44
1 kg of carbon will produce = 44/12
= 3.67 kg of CO_2
CO_2 absorbs 1000 kg of wood = 237.5 x 3.67
= 871.625 kg
CO_2 absorbs 10 kg of wood = 871.625/1000
= 8.72 kg

As per the Miyawaki forest method, the Wood of the Canopy layer & tree layer becomes 15 kg and the Shrub layer becomes 7 kg within 12 months. 3 to 5 trees and plants are planted by the Miyawaki method per square meter. So, an average of 60 kg of wood is within a square meter.

CO_2 absorbs per sq.m = 6 x 8.72kg
= 52.32 kg
Total number of days for production = 5 days x 12 months
= 60 days per year
Total emission of CO_2 per year = 0.004 x 60
= 0.24 kiloton
Total absorption of CO_2 per sq.m per year = 0.00005 kilotons.
The available area of the industry = 2750 m^2
Total absorption of CO_2 = 2750 x 0.00005 kiloton
= **0.138 kiloton**.
This method can be reduced the 60 % of CO_2 emission from the selected industry.

III. CONCLUSION

As per the calculation, the average CO_2 emission from the production of a concrete block in the selected industry is approx. 0.24 kiloton per year. As per the project, the absorption of CO_2 per sq.m is 52.32 kg by the Miyawaki forest method. The total absorption of CO_2 per year is about 0.138 kilotons. This means, by this method 60 % of total CO_2 emissions can be reduced within one year gradually.

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