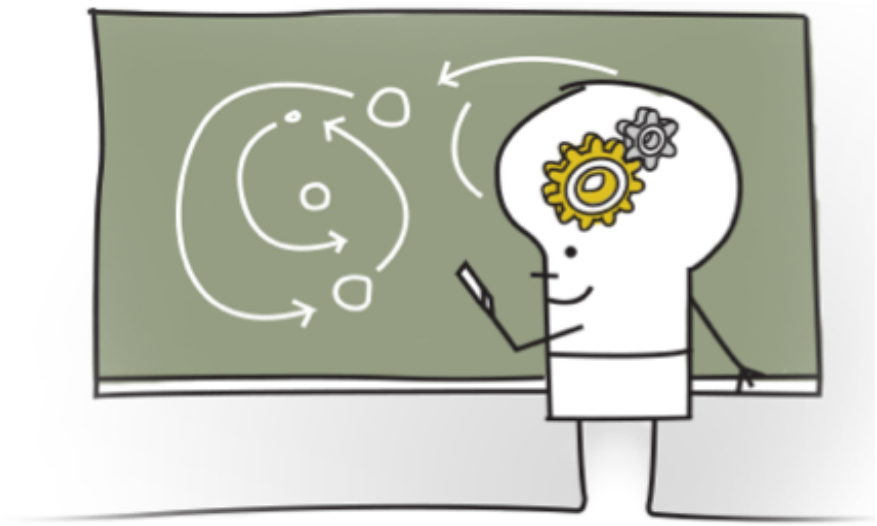
EFFECTS OF LOCKDOWN ON ENVIRONMENT

System Dynamics: Modeling & Simulation for Development



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INTRODUCTION

A lockdown is a restriction policy for people or communities to stay where they are, usually, due to specific risks, they pose to themselves or others if they move or interact freely. It is an emergency protocol to prevent people from leaving a given area. A full lockdown means that people have to stay where they are and not leave their place. This scenario usually allows essential services such as food supplies, ambulance services etc. to function without restriction to cater to people's needs.

The concept of lockdown has existed for a long time. It is used to control various natural and manmade situations such as terror attacks and pandemics. The practice of confinement was adopted by European countries like England and France during the 16th and 18th century to protect people from exposure to deadly disease from overseas. The latest lockdowns have happened throughout the world due to the outbreak of novel coronavirus. Various countries around the world including India announced emergency lockdown to curb the spread of the deadly virus. In this report, we study the effects of lockdown on the environment on its model dynamics.

ARTICLES

The effect of COVID-19 lockdown on the air environment in India

N. Gupta et al. in their paper study the effect of lockdown which was placed in India to control Covid-19 on air quality. They study the effect on various environmental parameters like aerosol, ozone, particulate matter, nitrogen dioxide, sulphur dioxide, carbon monoxide and temperature. Their work involves using raw data collected before and during the lockdown, preprocessing it and analysing it to gauge the impact of lockdown. Along with this, they have used satellite images collected from NASA for comparison of different parameters. They have observed that there has been a significant reduction in the temperature, humidity levels, particulate matter and gaseous pollutants. Since, most of the air pollutants can be attributed to transportation, industrial and economic activities, a significant reduction in these activities directly translated to reduced addition of pollution to the already severely affected atmosphere.

The good, the bad and the ugly of COVID-19 lockdown effects on wildlife conservation: Insights from the first European locked down country

In this study, Viola et al. have made use of the lockdown to understand how large scale

shifts of human activities can impact wildlife. The authors have done a qualitative analysis of social media information with field data from multiple taxa, data from citizen science projects, and questionnaires addressed to managers of protected areas. While field data confirmed some positive effects of lockdown on wildlife such as reduced human activity allowing animals to explore new habitats, increased daily activity, increase in species richness in temporarily less-distributed habitats, higher breeding success, it also highlighted negative impacts of the Covid-19 crisis on wildlife. Lower human disturbance linked to lockdown was in fact seen beneficial for invasive alien species. Wildlife conservation activities to protect threatened taxa were also hampered. According to the authors, a reduction in these wildlife conservation activities could also translate to a surge in illegal wildlife killing.

COVID-19 lockdown: A ventilator for rivers

The author in his article notes that India's water bodies are in a poor state. An estimated 40 million litres of wastewater is entering rivers and water bodies in India; only 37% of it is being treated. The river Ganga, one of the most important rivers of India has shown remarkable improvements in water quality. Within 10 days of the nationwide lockdown signs of improvement in water quality started surfacing. Monitoring stations showed improved dissolved oxygen levels. For example, at Varanasi's Nagwa Nala, the DO levels were found to increase by an astounding 79 percent. The main cause behind this is attributed to the stoppage of dumping of industrial wastes in the water. Other activities such as tourism, fairs, bathing and clothing activities near the ghats were curtailed and this contributed to the decrease in water pollution.

Impact of lockdown measures during COVID-19 on air quality– A case study of India

In this paper, the variation in concentration of key air pollutants including PM10, PM2:5, NO2, SO2 and O3 during two phases, pre-lockdown and post-lockdown phases, was analysed. The air quality data for four stations of Delhi, four stations of Mumbai and a single station of Singrauli for the period from 1st March 2020 to 15 April 2020 was obtained from CentralPollution Control Board (CPCB) online portal. Delhi and Mumbai are metropolitan cities of India that are enlisted in the most polluted cities of the world (CPCB 2014). The concentration of PM10, PM2:5, NO2 and SO2 reduced by 55% ,49%, 60% and 19%, and 44%, 37%, 78% and 39% for Delhi and Mumbai, respectively, during the post-lockdown phase. However, Singrauli has not shown any significant reduction in pollution levels due to the presence of coal-based power plants nearby which were not shut as being a part of the essential services.

Indirect impact of COVID-19 on the environment: A brief study in Indian context

In this paper, the researchers have studied the variation in air pollution and river quality with the induction of lockdown. The city under study for air pollution was Ghaziabad, which according to reports is one of the most polluted cities in India at par with Delhi. Ghaziabad is in first place with PM2.5 pollution level of 110.2 μg/m3 in 2019 compared to the permissible limit of 60 μg/m3 (for 24 h) (IQAir report, 2019). They have also discussed air pollution based on the air quality index. They have found that the $PM_{2.5}$ concentration in Ghaziabad has come down by 85%. The other pollutant concentrations have also come down significantly. The water pollution has come down and marine life has become more visible.

Why Covid-19 will end up harming the environment?

This article describes the long term effects of Covid-19 on the environment. The economic impact of Covid-19 will cause the rules and regulations for saving the environment to be loosened. The funds allocated for environment conservation would be redirected to other areas. In short, the small positive impacts of lockdown on the environment are short term.

Environmental effects of COVID-19 pandemic and potential strategies of sustainability

This paper by Tanjena Rume and et al. describes the positive and negative impacts of covid lockdown on the environment. There have been a lot of positive impacts on the environment due to covid lockdown. Aviation and cars are major sources of pollution, and due to none of them being in operation, air pollution has drastically decreased. Due to vehicles not being in operation, a lesser amount of crude oil is being used. The Ozone layer is recovering much faster. The NO2 and CO2 levels have dropped, causing lesser acid rains, decrease in respiratory diseases for many. Lockdown has stopped all industrial activities, and fishing activities, therefore the garbage being dumped into water and fishing is practically zero. This significantly reduces water pollution and encourages aquatic life to thrive and also gives us cleaner water.
The covid lockdown has also shown some negative impacts. Primarily an increase in biomedical waste. To disinfect the surroundings a huge biomedical waste is generated. There is an increase in the production of plastic materials such as gloves, PPE kits, face shields etc. and disposing of this leads to an increase in toxins to the environment.

Polypropylene is used heavily in the preparation of N95 masks. Polypropylene when disposed of, ends up releasing a chemical that can persist for a long time in the environment called dioxin and also some other toxic elements. Also, due to lockdown, many establishments have postponed the recycling process which is causing a lot of garbage to be accumulated and this can cause diseases. Due to an increase in the use of disinfectants in the environment, these disinfectants are causing non targeted microorganisms to perish and this will cause an imbalance in the ecosystem.

MODEL

THE LOCKDOWN

This model's time units are in terms of Weeks. We have modelled it in such a way that between week number 20 and 30, there will be a lockdown. IF ELSE condition used to trigger a variable between these time steps to indicate a lockdown. Based on this indicator, many activities ,including day to day activities will be affected.

Sl. No	Variable Name	Equation	Units
1.	Lockdown	IF THEN ELSE(Time>=20 :AND: Time<=30, 1 , IF THEN ELSE(Time=31 , 2 , 0))	Dmnl

The nested IF ELSE condition activates when the lockdown is over. We use this third variable to show that lockdown is now complete, i.e. from week 31 onwards, and the rate of increase in activity will slowly increase instead of increasing our activities at the rate at which we stopped them when the lockdown had started in week 20.

INDUSTRIAL ACTIVITIES

Industrial activities include activities like mining, manufacturing along with assembling and repair (Eg., automobile industry), and service oriented industries like information technology. They require machines, labour, management and research and development to run. These activities can contribute directly or indirectly to pollution as shown in Fig

1.

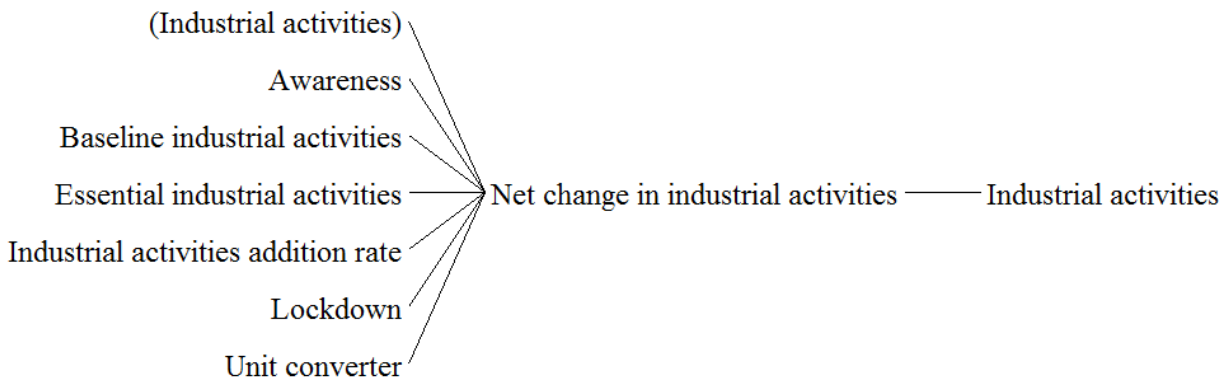

Fig.1: Causes tree of Industrial activities

With economic development and population growth in order to meet the needs of the people the industrial activities increase which is included in the model by industrial activities addition rate.When lockdown is imposed most of the industrial activities have to be stopped while “Essential industrial activities” like food processing, manufacturing of medical equipment continue to work even during lockdown. Also service based industries like information technology can be run by their employees working from home. Once the lockdown is removed the stopped industrial activities starts again.

SNo	Stock/Flow/variable	Equation and initial value	Units
1	Industrial activities	=INTEG (Net change in industrial activities,1000)	IA
2	Net change in industrial activities	=IF THEN ELSE(Lockdown=1 , (-Industrial activities + Essential industrial activities)/Unit converter , IF THEN ELSE(Lockdown =2, Baseline industrial activities/Unit converter, (Industrial activities*Industrial activities addition rate)/Awareness))	IA/Week
3	Awareness	= (1 + Health risk)	Dmnl
4	Baseline industrial activities	=1000	IA

5	Essential industrial activities	=100	IA
6	Industrial activities addition rate	=0.001	1/Week
7	Lockdown	=IF THEN ELSE(Time>=20 :AND: Time<=30, 1 , IF THEN ELSE(Time=31 , 2 , 0))	Dmnl
8	Unit converter	= 1	Week

Table 1: Equations and units of Industrial Activities

WILDLIFE CONSERVATION ACTIVITIES

There have been some positive impacts of lockdown on wildlife [3] like reduced human activity allowing animals to explore new habitats, increased daily activity, increase in species richness in temporarily less-distributed habitats, higher breeding success etc. But, there are some negative impacts of lockdown on wildlife like it supported invasive alien species causing detrimental effects on local flora and fauna. Also there has been reduction in wildlife conservation activities, which provided an opportunity for illegal poaching and hunting.

In our model we have tried to include the impact lockdown of wildlife conservation activities.

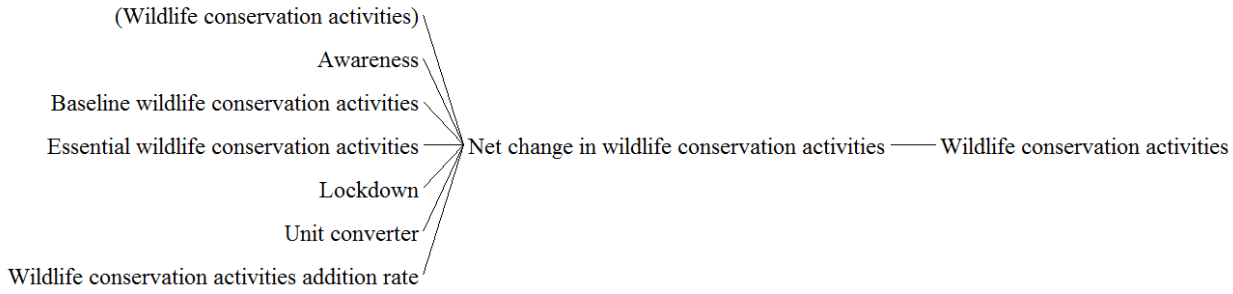

Fig.2: Causes tree of wildlife conservation activities

Sl No.	Variable Name	Equation	Units
1	Wildlife conservation activities	= INTEG (Net change in wildlife conservation activities,1000)	WCA
2	Net change in wildlife conservation activities	=IF THEN ELSE(Lockdown=1 , (-Wildlife conservation activities + Essential wildlife conservation activities)/Unit converter , IF THEN ELSE(Lockdown=2, Baseline wildlife conservation activities/Unit converter, (Wildlife conservation activities*Wildlife conservation activities addition rate)*Awareness))	WCA/Week
3	Baseline wildlife conservation activities	= 1000	WCA
4	Essential wildlife conservation activities	=100	WCA
5	Wildlife conservation activities addition rate	= 0.001	Units: 1/Week

Table 2: Equations and units of wildlife conservation activities

TOURISM AND LEISURE ACTIVITIES

Tourism activities across the globe has come to a standstill with covid-19 and during the lockdown it was virtually impossible.Lots of people lost their jobs and it has affected severely the economies which depended mostly on tourism.Before the lockdown tourism was in fact booming and it was growing faster than GDP globally.

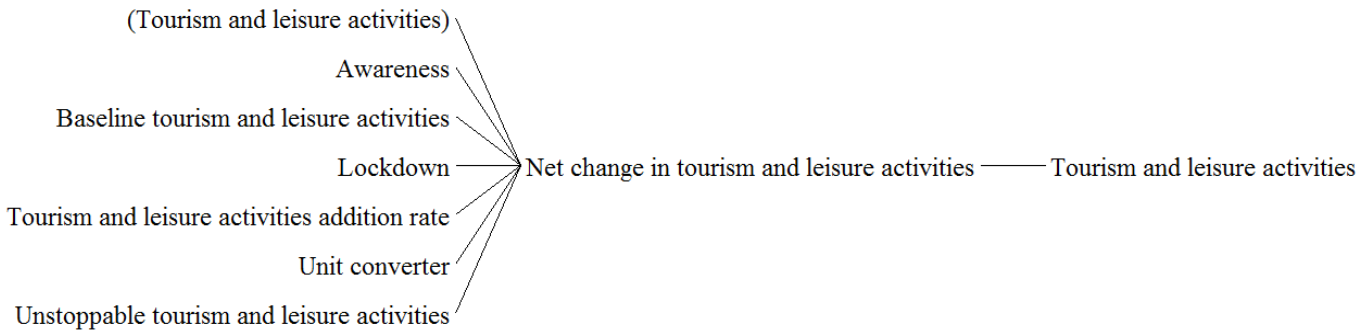

Fig.3: Causes tree of tourism and leisure activities

With reduction in tourism activities primarily the number of vehicles, even ships and aeroplanes reduces drastically. Which in turn reduces the pollution caused by these vehicles. Also there is significant reduction of waste accumulation in and around tourist destinations and thereby water and soil pollution.Further details of approximate dependence of pollution to tourism and leisure activities are given in Table 4.

Sl No.	Variable Name	Equation	Units
1	Tourism and leisure activities	= INTEG (Net change in tourism and leisure activities,1000)	TLA

2	Net change in tourism and leisure activities	=IF THEN ELSE(Lockdown=1 , (-Tourism and leisure activities + Unstoppable tourism and leisure activities)/Unit converter, IF THEN ELSE(Lockdown=2, Baseline tourism and leisure activities/Unit converter , (Tourism and leisure activities*Tourism and leisure activities addition rate)*Awareness))	TLA/Week
3	Baseline tourism and leisure activities	=1000	TLA
4	Unstoppable tourism and leisure activities	= 10	TLA
5	Tourism and leisure activities addition rate	=0.005	1/Week

Table 3: Equations and units of Tourism and Leisure activities

FARMING ACTIVITIES

Farming activities were disrupted during lockdown due to migrant workers going back to their native place in the havoc of the pandemic, and also due to shortage of raw materials and machinery. But we all need food, so some amount of farming activities had continued during the lockdown. Also the governments all over the world tried to support the farmers to restart farming immediately after lockdown.We have also tried to model the demand and supply corresponding with population. There has been a rise in awareness about the importance of sustainable farming, and some people at home during lockdown have started to do farming in their backyard.

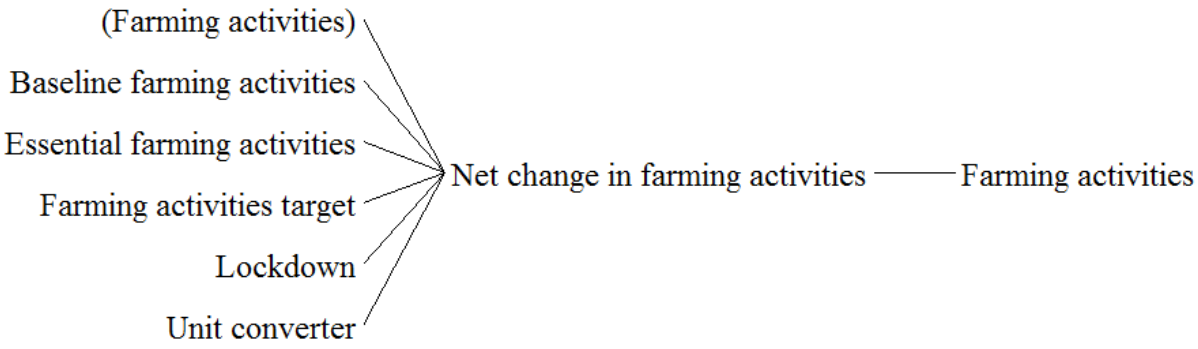

Fig. 4: Causes tree of Farming activities

Sl No.	Variable name	Equation	Units
1	Farming activities	= INTEG (Net change in farming activities,1000)	FA
2	Net change in farming activities	= IF THEN ELSE(Lockdown=1 , (-Farming activities + Essential farming activities)/Unit converter , IF THEN ELSE(Lockdown=2,(-Essential farming activities + Baseline farming activities)/Unit converter, (MAX((Farming activities target-Farming activities)/Unit converter, 0))))	FA/Week
3	Baseline farming activities	=1000	FA
4	Essential farming activities	= 500	FA

5	Farming activities target	=Baseline farming activities*Food demand	FA

Table 4: Equations and units of farming activities

VEHICLES

Vehicles contribute majorly to the environment's pollution. We discuss about 3 vehicle types and their contribution to the environment's pollution in this report. The three types of vehicles are:

1. Road vehicles (Cars, bikes, buses etc.)
2. Marine Vehicles (Fishing boats, cruise ships etc.)
3. Air vehicles (Airplanes, private jets, helicopters etc.)

ROAD VEHICLES

The road vehicles stock gives us a simulated number of vehicles on the road during a certain period of time. We use this number to determine how it affects the pollution to the environment. Such as air pollution, water pollution, soil pollution, noise pollution. The number of vehicles on road are determined by the day to day activities and also the regulations, and environmental awareness of the people. Mainly, the major contribution to the cars are the industrial activities. Based on our literature survey we found that more the production, more the vehicles on road. Fig. 7 shows how road vehicles are affected.

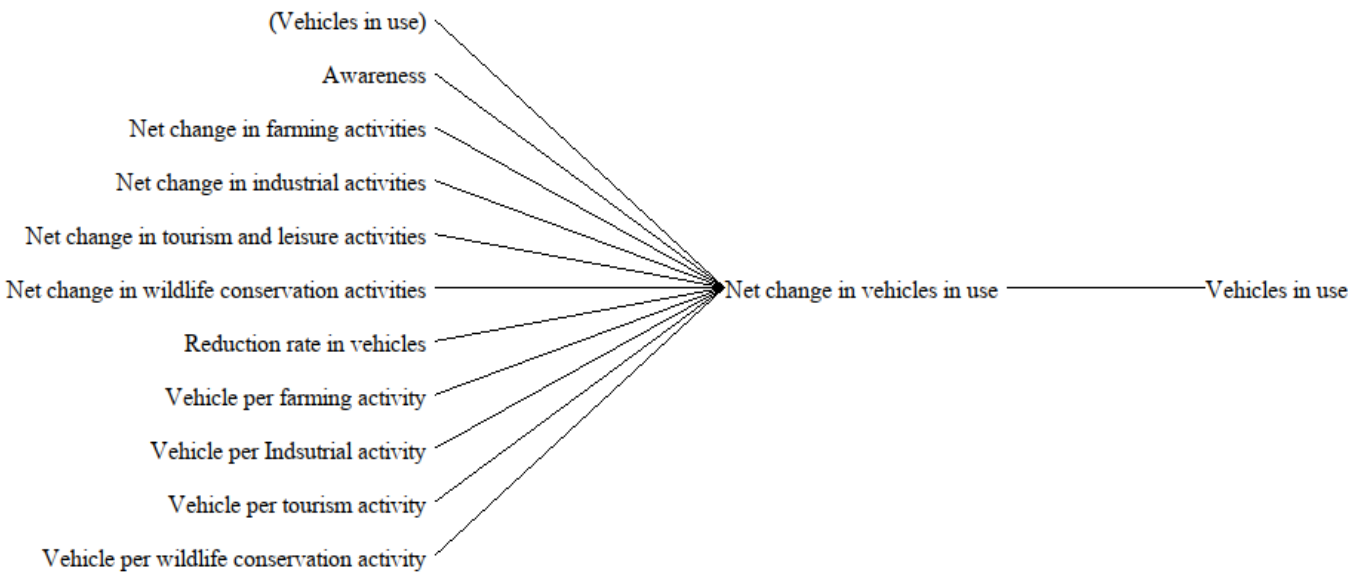

Fig.5: Causes tree of Vehicles in use

Sl. No	Variable Name	Equation	Units
1.	Vehicles in use	Net change in vehicles in use	Car
2.	Net change in vehicles in use	(((Net change in farming activities*Vehicle per farming activity)+(Net change in industrial activities*Vehicle per Industrial activity)+(Net change in tourism and leisure activities*Vehicle per tourism activity)+(Net change in wildlife conservation activities*Vehicle per wildlife conservation activity))/Awareness)-(Reduction rate in vehicles * Vehicles in use)	Car/Week
3.	Awareness	(1 + Health risk)	Dmnl
4.	Net change in farming activities	IF THEN ELSE(Lockdown=1 , (-Farming activities + Essential farming activities)/Unit converter , IF THEN ELSE(Lockdown=2, (-Essential farming activities + Baseline farming activities)/Unit converter, (MAX((Farming activities target-Farming activities)/Unit converter, 0))))	FA/Week

5.	Net change in Industrial activities	IF THEN ELSE(Lockdown=1 , (-Industrial activities + Essential industrial activities)/Unit converter , IF THEN ELSE(Lockdown=2, Baseline industrial activities/Unit converter, (Industrial activities*Industrial activities addition rate)/Awareness))	IA/Week
6.	Net change in Tourism and Leisure activities	IF THEN ELSE(Lockdown=1 , (-Tourism and leisure activities + Unstoppable tourism and leisure activities)/Unit converter , IF THEN ELSE(Lockdown=2, Baseline tourism and leisure activities/Unit converter , (Tourism and leisure activities *Tourism and leisure activities addition rate)*Awareness))	TLA/Week
7.	Net change in wildlife conservation activities	IF THEN ELSE(Lockdown=1 , (-Wildlife conservation activities + Essential wildlife conservation activities)/Unit converter , IF THEN ELSE(Lockdown=2, Baseline wildlife conservation activities/Unit converter , (Wildlife conservation activities *Wildlife conservation activities addition rate)*Awareness))	WCA/Week
8.	Reduction rate in vehicles in use	0.001	1/Week
9.	Vehicles per farming activity	1	Car/FA
10.	Vehicles per Industrial activity	2	Car/IA
11.	Vehicles per tourism	1	Car/TLA

	and leisure activity		
12.	Vehicles per wildlife conservation activity	1	Car/WCA

Table 5: Equations and units determining road vehicles in use.

MARINE VEHICLES

The marine vehicles stock gives us a simulated number of marine vehicles in use. This number is affected by a variety of factors, such as industrial activities, farming activities, awareness of environmental pollution. Based on our literature survey, marine vehicles tend to pollute the seas, rivers and oceans by leaving behind a lot of plastic waste and dumping garbage. Oil spillage is also a major water pollutant. Most of these vehicles are fishing boats, these tend to disrupt the natural ecological habitat of aquatic life. In our model, we show how pollution is affected when these activities are stopped due to lockdown. Fig. 7 shows the cause tree for the marine vehicles stock.

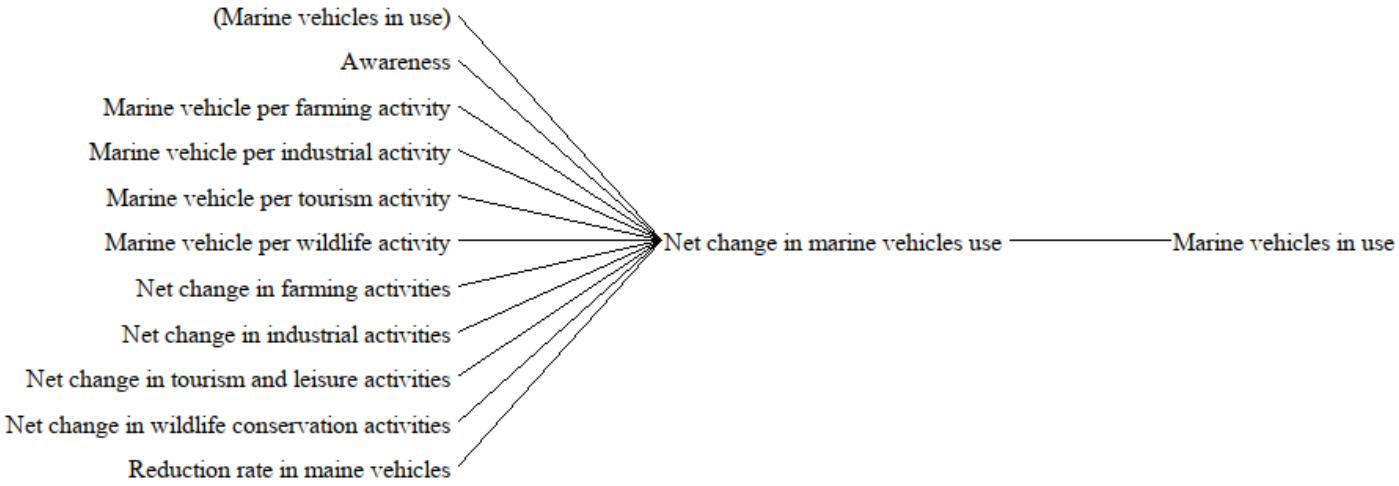

Fig. 6: Causes tree of Marine vehicles in use

Sl. No	Variable Name	Equation	Units

1.	Marine Vehicles in use	Net change in Marine vehicles in use	Car
2.	Net change in Marine vehicles in use	(((Net change in farming activities*Vehicle per farming activity)+(Net change in industrial activities*Vehicle per Industrial activity)+(Net change in tourism and leisure activities*Vehicle per tourism activity)+(Net change in wildlife conservation activities*Vehicle per wildlife conservation activity))/Awareness)-(Reduction rate in vehicles*Vehicles in use)	BoatWeek
3.	Awareness	(1 + Health risk)	Dmnl
4.	Net change in farming activities	IF THEN ELSE(Lockdown=1 , (-Farming activities + Essential farming activities)/Unit converter , IF THEN ELSE(Lockdown=2, (-Essential farming activities + Baseline farming activities)/Unit converter, (MAX((Farming activities target-Farming activities)/Unit converter, 0))))	FA/Week
5.	Net change in Industrial activities	IF THEN ELSE(Lockdown=1 , (-Industrial activities + Essential industrial activities)/Unit converter , IF THEN ELSE(Lockdown =2, Baseline industrial activities/Unit converter, (Industrial activities*Industrial activities addition rate)/Awareness))	IA/Week
6.	Net change in Tourism and Leisure activities	IF THEN ELSE(Lockdown=1 , (-Tourism and leisure activities + Unstoppable tourism and leisure activities)/Unit converter, IF THEN ELSE(Lockdown=2, Baseline tourism and leisure activities/Unit converter , (Tourism and leisure activities*Tourism and leisure	TLA/Week

		activities addition rate)*Awareness))	
7.	Net change in wildlife conservation activities	IF THEN ELSE(Lockdown=1 , (-Wildlife conservation activities + Essential wildlife conservation activities)/Unit converter, IF THEN ELSE(Lockdown=2, Baseline wildlife conservation activities/Unit converter , (Wildlife conservation activities*Wildlife conservation activities addition rate)*Awareness))	WCA/Week
8.	Reduction rate in Marine vehicles in use	0.001	1/Week
9.	Marine vehicles per farming activity	1	Boat/FA
10.	Marine vehicles per Industrial activity	2	Boat/IA
11.	Marine vehicles per tourism and leisure activity	1	Boat/TLA
12.	Marine vehicles per wildlife conservation activity	1	Boat/WCA

Table 6: Table of equations, units and variables involved in determining the marine vehicles in use.

AIR VEHICLES

The air vehicles in use stock gives us a simulated number of air vehicles in use. It is one of the contributors for pollution. During a lockdown, as per our literature surveys. All non essential air vehicles are stopped. No commercial planes are flown. This reduces the carbon footprint released to the environment. In our model we show how this affects our pollution models, such as air pollution, water pollution etc. Fig. 8 depicts the causes tree

representation of Air vehicles in use.

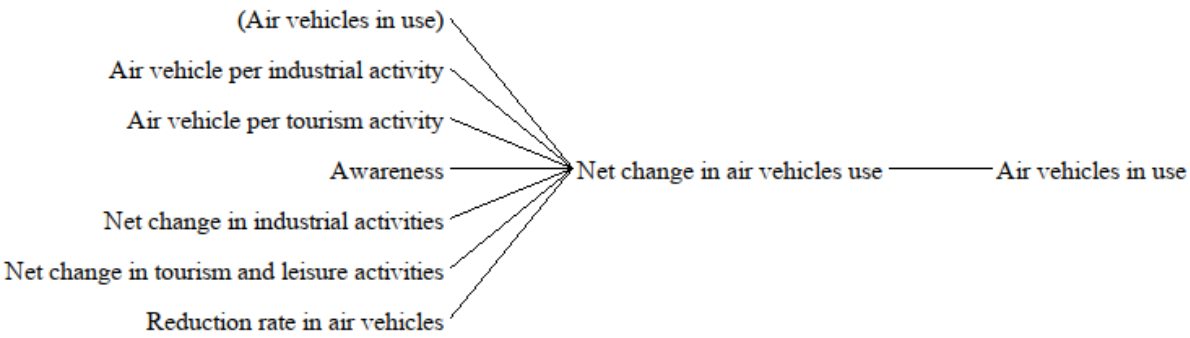

Fig. 7: Causes tree of Air vehicles in use

Sl. No	Variable Name	Equation	Units
1.	Air Vehicles in use	Net change in Air vehicles in use	Airplane
2.	Net change in Air vehicles in use	(((Net change in farming activities*Vehicle per farming activity)+(Net change in industrial activities*Vehicle per Industrial activity)+(Net change in tourism and leisure activities*Vehicle per tourism activity)+(Net change in wildlife conservation activities*Vehicle per wildlife conservation activity))/Awareness)-(Reduction rate in vehicles*Vehicles in use)	Airplane/Week
3.	Awareness	(1 + Health risk)	Dmnl

4.	Net change in Industrial activities	IF THEN ELSE(Lockdown=1 , (-Industrial activities + Essential industrial activities)/Unit converter , IF THEN ELSE(Lockdown=2, Baseline industrial activities/Unit converter, (Industrial activities*Industrial activities addition rate)/Awareness))	IA/Week
5.	Net change in Tourism and Leisure activities	IF THEN ELSE(Lockdown=1 , (-Tourism and leisure activities + Unstoppable tourism and leisure activities)/Unit converter, IF THEN ELSE(Lockdown=2, Baseline tourism and leisure activities/Unit converter , (Tourism and leisure activities *Tourism and leisure activities addition rate)*Awareness))	TLA/Week
6.	Reduction rate in Air vehicles in use	0.001	1/Week
7.	Air vehicles per Industrial activity	2	Airplane/IA
8.	Air vehicles per tourism and leisure activity	1	Airplane/TLA

Table 7: Equations and units involved in determining air vehicles in use.

AIR POLLUTION

Based on our survey, and research, air pollution was one of the pollutants that majorly reduced during a lockdown. We simulate and prove this in our model by taking into account multiple factors. The unit for air pollution is micrograms/m3. This measure tells us how many pollutants are present in the air per meter cube. The pollutants that pollute our air are majorly from Industrial activities, and the different types of vehicles. During a lockdown, these activities are reduced to the bare minimum and this inturn reduces air pollution significantly. Due to air pollution, acid rains can occur. These acid rains do

harm to the water causing water pollution, our soil and also our health. The main pollutants are PM2.5, Carbon monoxide, Carbon dioxide, Nitrous Oxide. These gases also play a part in global warming. But in our model, we show the risks directly from air pollution to our health and we will not be discussing global warming as it is a much broader topic. Below is an image(Fig. 8) which shows the causes graph for the Air pollution stock in our model.

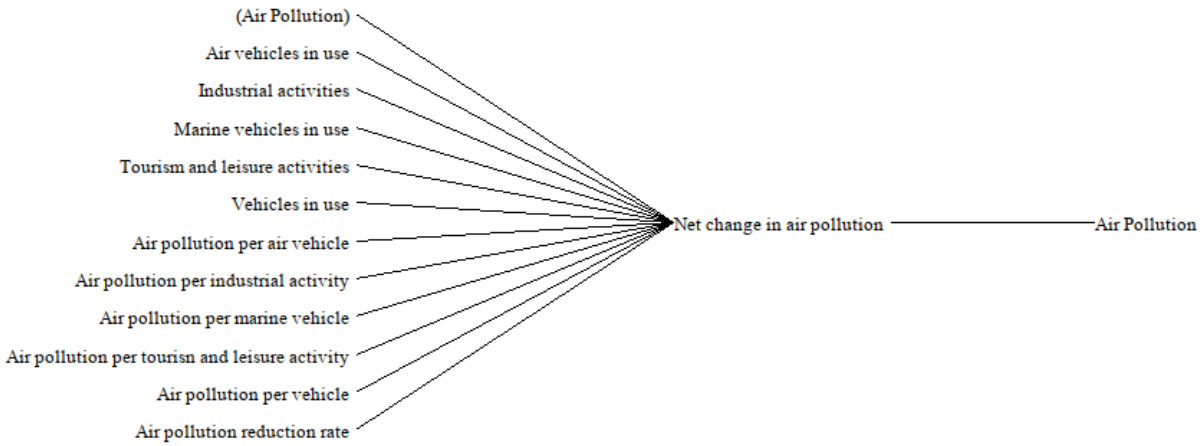

Fig. 8: Causes tree of Air pollution

Sl. No	Variable Name	Equation	Units
1.	Air Pollution	Net change in Air pollution	micrograms/m3
2.	Net change in Air pollution	(((Air pollution per air vehicle*Air vehicles in use)+(Air pollution per industrial activity*Industrial activities)+(Air pollution per marine vehicle*Marine vehicles in use)+(Air pollution per tourism and leisure activity*Tourism and leisure activities)+(Air pollution per vehicle*Vehicles in use))) - (Air Pollution*Air pollution reduction rate)	(micrograms/m3)/Week
3.	Air vehicles in use	Net change in air vehicles in use	Airplane

4.	Road vehicles in use	Net change in road vehicles in use	Car
5.	Marine vehicles in use	Net change in marine vehicles in use	Boat
6.	Industrial activities	Net change in industrial activities	IA
7.	Tourism and leisure activities	Net change in tourism activities	TLA
8.	Air pollution per Industrial activity	0.001	(micrograms/m3)/(IA*Week)
9.	Air pollution per vehicle	0.008	(micrograms/m3)/(Car*Week)
10.	Air pollution per marine vehicle	0.00075	(micrograms/m3)/(Boat*Week)
11.	Air pollution per air vehicle	0.0008	(micrograms/m3)/(Airplane*Week)
12.	Air pollution per tourism and leisure activity	0.0005	(micrograms/m3)/(TLA*Week)
13.	Air pollution reduction rate	0.03 + (0.01*Air pollution reduction rate multiplier)/Unit converter	1/Week

Table 8: Equations and units determining Air pollution level

SOIL POLLUTION

Based on our survey and research, we find that soil pollution mainly occurs when using pesticides. These pesticides are used for agricultural activities to prevent pests from eating away a farmer's produce. Industrial activities are also a big contributor to soil

pollution. Waste from factories and industries are mainly dug up and dumped into the environment. This causes a lot of chemicals to enter into the soil, degrading the fertility of the soil and increasing the danger in the crops we eat due to these chemicals. We modelled the causes for our Soil pollution stock, and simulated it. The pollution does not seem to reduce very significantly as compared to the other pollution levels. Air pollution and water pollution also seem to affect soil pollution via Acid rains and impure water.

Fig.9 is an image of the causes tree for Soil pollution stock.

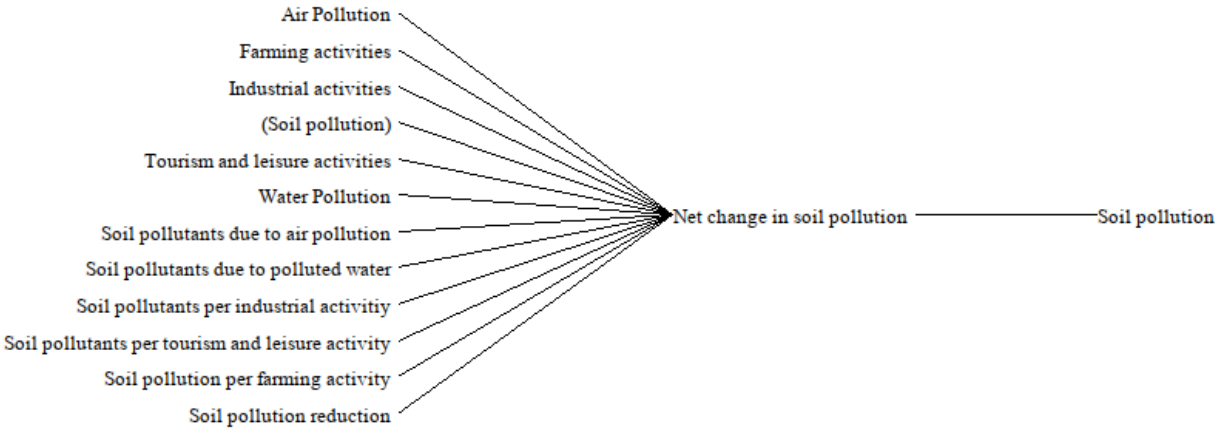

Fig. 9: Causes tree of soil pollution

Sl. No	Variable Name	Equation	Units
1.	Soil Pollution	Net change in Soil pollution	kilograms/m3
2.	Net change in Soil pollution	((Air Pollution*Soil pollutants due to air pollution)+(Industrial activities*Soil pollutants per industrial activity)+(Water Pollution*Soil pollutants due to polluted water)+((Soil pollution per farming activity*Farming activities))+(Soil pollutants per tourism and leisure activity*Tourism and leisure activities))-(Soil pollution*Soil pollution reduction)	(kilograms/m3)/Week
3.	Air pollution	Net change in Air pollution	micrograms/m3
4.	Farming activities	Net change in farming activities	FA
5.	Industrial activities	Net change in Industrial activities	IA

6.	Tourism and leisure activities	Net change in tourism activities	TLA
7.	Water pollution	Net change in water pollution	KiloLitres
8.	Soil pollutants due to air pollution	0.02	(kilograms/m3)/((micrograms/m3)*Week)
9.	Soil pollutants to due to polluted water	0.05	(kilograms/m3)/(KiloLitres*Week)
10.	Soil pollutants per industrial activity	0.25	(kilograms/m3)/(IA*Week)
11.	Soil pollutants per tourism and leisure activity	0.01	(kilograms/m3)/(TLA*Week)
12.	Soil pollutants per farming activity	0.1*(Adjusted pesticide usage per farming activity/m3 Unit converter)	kilograms/(Week*m3*FA)
13.	Adjusted pesticide usage per farming activity	Baseline pesticide usage per farming activity/Awareness	kilograms/(FA*Week)
14.	Baseline pesticide usage per farming activity	1	kilograms/(FA*Week)

Table 9: Equations and units determining soil pollution levels

WATER POLLUTION

The state of rivers in India is really alarming. The release of waste and toxic chemicals by industrial activities and vehicles is destroying our aquatic ecosystem. Also the widespread use of pesticides and fertilizers causes them to run into nearby water bodies and further into rivers and oceans and thus degrading the water quality. This inturn is significantly affecting the health of people as the water they consume is contaminated and the fish they eat is toxic. During the lockdown we could hear a lot of news on the

water bodies across the world becoming clear and more rare species of aquatic life being spotted. There has been a rise in dissolved oxygen in water in this short term of lockdown.

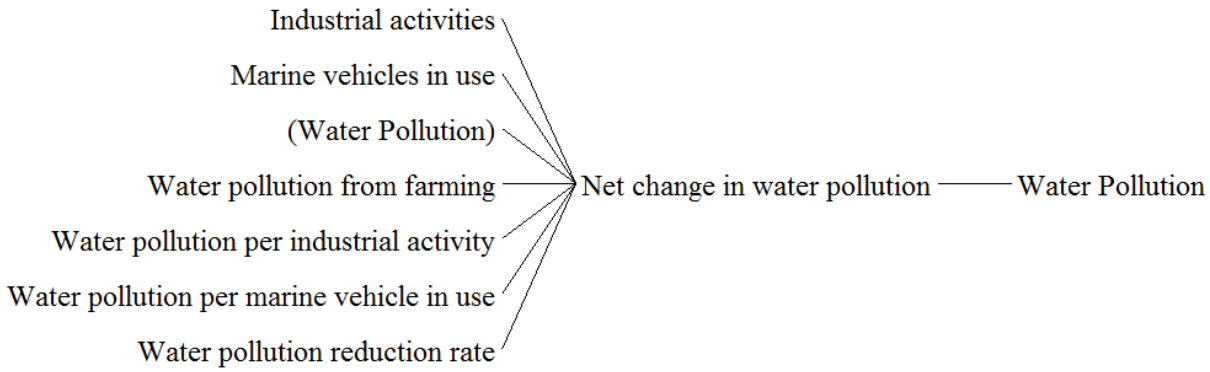

Fig. 10: Causes tree of water pollution

Sl No	Variable	Equation	Units
1	Water Pollution	= INTEG (Net change in water pollution,1000)	KiloLitres
2	Net change in water pollution	= ((Industrial activities*Water pollution per industrial activity)+(Marine vehicles in use*Water pollution per marine vehicle in use)+Water pollution from farming)-(Water Pollution reduction rate*Water Pollution)	KiloLitres/Week
3	Water pollution per marine vehicle in use	=0.0075	KiloLitres/(Boat*Week)

4	Water pollution per industrial activity	= 0.05	KiloLitres/(IA*Week)
5	Water pollution from farming	=(Farming activities*Adjusted pesticide usage per farming activity)*Average water pollution per KG of pesticide usage	KiloLitres/Week
6	Water pollution reduction rate	=0.02	1/Week

Table 10: Equations and units determining water pollution levels

NOISE POLLUTION

Noise pollution is causing health problems in humans and animals in the long run. It causes anxiety, sleep disturbance, hypertension and hormonal dysfunctions. As shown in fig the primary sources of noise pollution are industrial activities and vehicles in use. With reduced industrial activities and vehicles in use during lockdown the noise levels in urban areas have come down significantly to allowed limits.

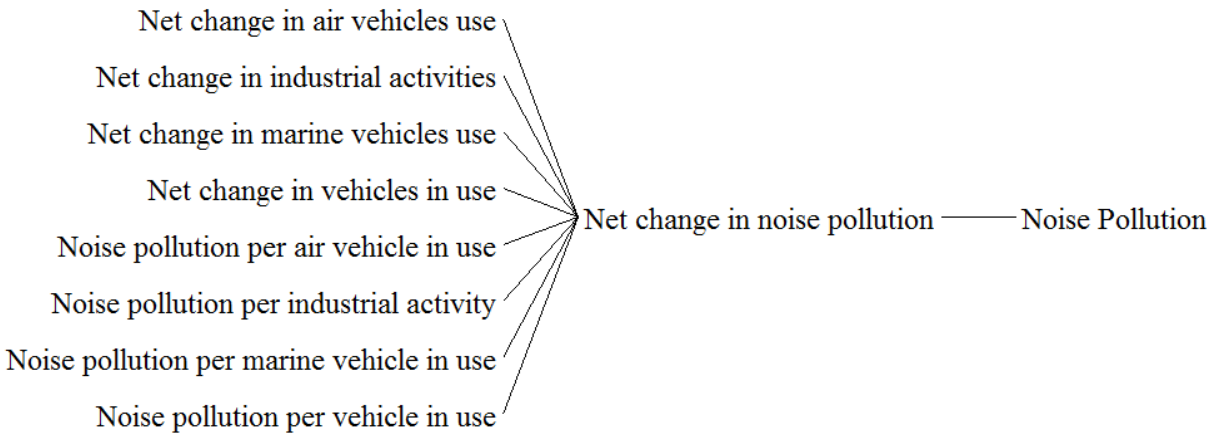

Fig. 10: Causes tree of noise pollution

SNo	Stock/Flow/variable	Equation and initial value	Units
1	Noise Pollution	= INTEG (Net change in noise pollution,50)	Decibels
2	Noise pollution per air vehicle in use	= 0.0075	Decibels/Air plane
3	Noise pollution per marine vehicle in use	=0.01	Decibels/Boat
4	Noise pollution per vehicle in use	= 0.003	Decibels/Car
5	Noise pollution per industrial activity	= 0.01	Decibels/IA

Table 11: Equations and units determining noise pollution levels

HEALTH RISK INDICES

AIR POLLUTION HEALTH RISK

This is a variable that depends on the air pollution. This index's variable has a lower limit value of 0 (very less air pollution) and goes to 0.25 (indicates very high air pollution). This index depends on the Air pollution levels, acceptable air pollution level variable and a lookup which is predefined for the Air pollution levels. Below is a lookup graph for the health index against air pollution. This lookup variable is named as "Air pollution health risk lookup". The resulting graph(Fig. 11) of this variable indicates that the air pollution health index shows a decrease in value during the lockdown period due to reduction in Industrial activities, Vehicles in use and so on.

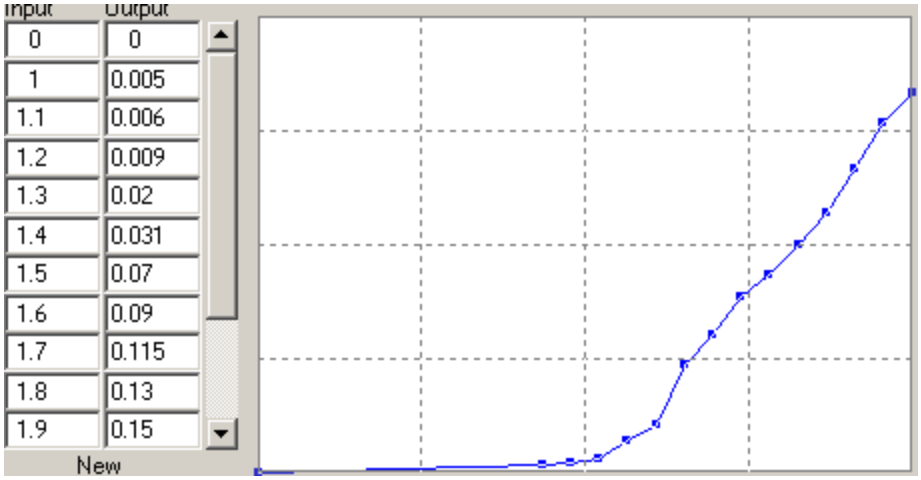

Fig. 11: Air pollution health risk look up graph

Sl. No	Variable Name	Equation	Units
1.	Air pollution health risk	Air pollution health risk lookup(Air Pollution/Acceptable air pollution levels)	Dmnl
2.	Acceptable air pollution levels	80	micrograms/m3
3.	Air pollution	Net change in Air pollution	micrograms/m3

Table 12: Equations and units determining air pollution health risk

WATER POLLUTION HEALTH RISK

This is a variable in our model which is dependent on the Water pollution level that we have modelled. This index's variable has a lower limit value of 0 (very less water pollution) and goes to 0.25 (indicates very high water pollution). This index depends on the Water pollution levels, acceptable Water pollution level variable and a lookup which is predefined for the Water pollution levels. Fig. 12 is a lookup graph for a health index against water pollution. This lookup variable is named as "Water pollution health risk lookup". The resulting graph of this variable indicates that the water pollution health index shows a decrease in value during the lockdown period due to reduction in Industrial activities, Vehicles in use and so on, which has decreased the water pollution

levels significantly.

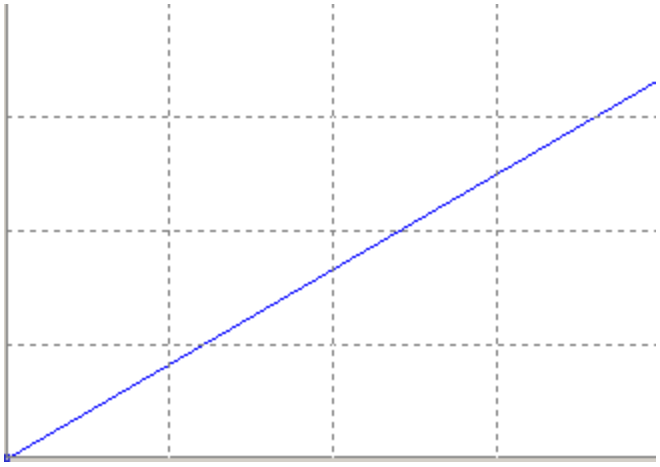

Fig. 12: Water pollution health risk look up graph

Sl. No	Variable Name	Equation	Units
1.	Water pollution health risk	Water pollution health risk lookup(Water Pollution/Acceptable water pollution levels)	Dmnl
2.	Acceptable water pollution levels	80	KiloLitres
3.	Water pollution	Net change in water pollution	KiloLitres

Table 13: Equations and units determining water pollution health risk

NOISE POLLUTION HEALTH RISK

This is a variable in our model which is dependent on the Noise pollution level that we have modelled. This index's variable has a lower limit value of 0 (very less noise pollution) and goes to 0.25 (indicates very high noise pollution). This index depends on the Noise pollution levels, acceptable Noise pollution level variable and a lookup which is predefined for the Noise pollution levels. Fig. 13 is a lookup graph for the health index against noise pollution. This lookup variable is named as "Noise pollution health risk lookup". The resulting graph of this variable indicates that the noise pollution health index shows almost no risk during the lockdown period due to reduction in the main activities that contribute to the sound.

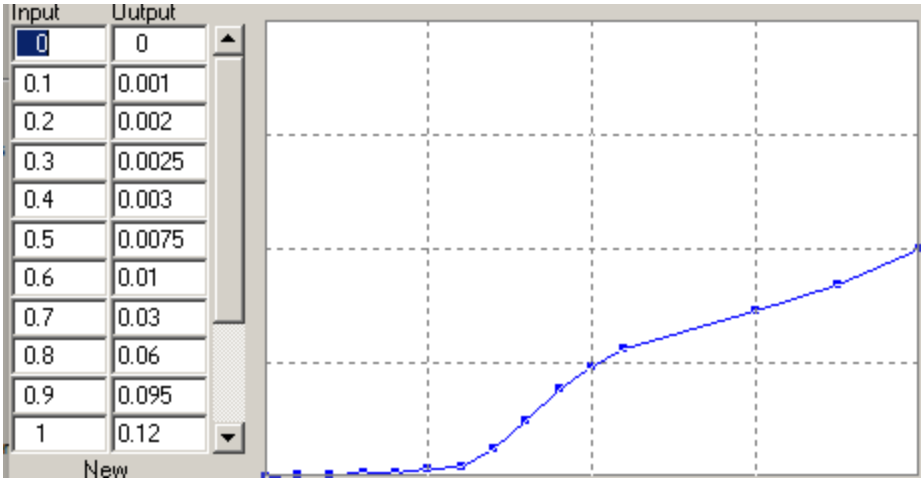

Fig. 13: Noise pollution health risk look up graph

Sl. No	Variable Name	Equation	Units
1.	Noise pollution health risk	Noise pollution health risk lookup(Noise Pollution/Acceptable noise pollution levels)	Dmnl
2.	Acceptable Noise pollution levels	80	decibels
3.	Noise pollution	Net change in noise pollution	decibels

Table 14: Equations and units determining noise pollution health risk

SOIL POLLUTION HEALTH RISK

This is a variable in our model which is dependent on the Soil pollution level that we have modelled. This index's variable has a lower limit value of 0 (very less soil pollution) and goes to 0.25 (indicates very high soil pollution). This index depends on the soil pollution levels, acceptable soil pollution level variable and a lookup which is predefined for the soil pollution levels. Fig. 14 is a lookup graph for a health index against soil pollution. This lookup variable is named as "Soil pollution health index lookup". The resulting graph of this variable indicates that the soil pollution health index shows a lesser increase in value during the lockdown period due to reduction in Industrial

activities, Vehicles in use and so on.

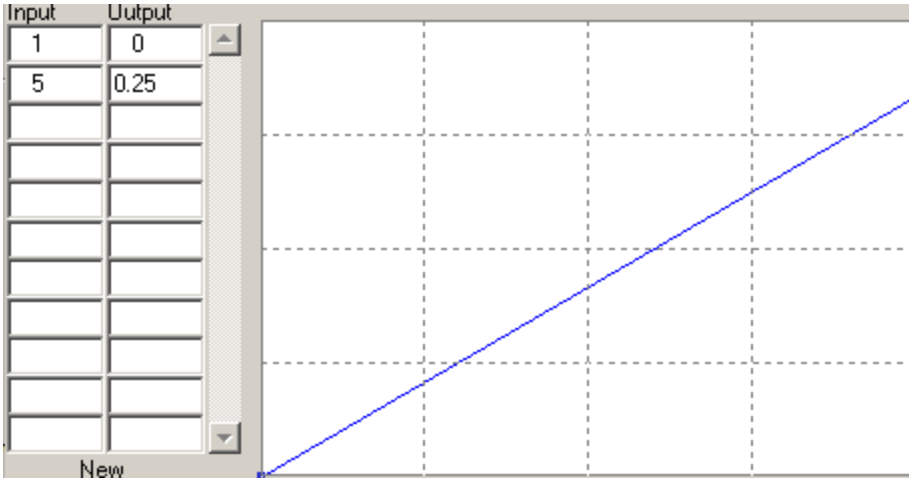

Fig. 14: Soil pollution health risk look up graph

Sl. No	Variable Name	Equation	Units
1.	Soil pollution health risk	Soil pollution health risk lookup(soil Pollution/Acceptable soil pollution levels)	Dmnl
2.	Acceptable soil pollution levels	80	Kilograms/m3
3.	Soil pollution	Net change in soil pollution	Kilograms/m3

Table 15: Equations and units determining soil pollution health risk

OVERALL HEALTH RISK

This index variable is a cumulative addition of all the indexes shown previously. The range is from 0 to 1. 0 being lowest risk to human health and 1 being at a very high risk to human health. We can see from our simulation that, during a lockdown, the health risk index goes to a safer zone as the pollutants in the atmosphere tend to decrease a lot.

Sl. No	Variable Name	Equation	Units

1.	Health risk	Air pollution health risk+Noise pollution health risk+Soil pollution health risk+Water pollution health risk	Dmnl

Table 16: Equations and units determining overall health risk

FEEDBACK LOOP: AWARENESS

With lockdown everyone had a glimpse of how nature recovers when we stop degrading it. This has raised awareness in human beings on the importance of urgent action to control the activities which degrade nature. Also with education and people understanding the health risk awareness to take suitable measures rises.

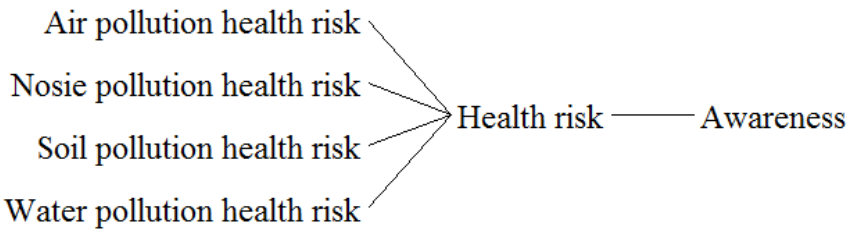

Fig. 15: Causes tree of awareness

SIMULATION AND RESULTS

LOCKDOWN

Fig. 15, shows the simulation results of the lockdown variable. Between time units 0-20, lockdown has a value of 0, between 20-30 lockdown has a value of 1 and at time unit 31, lockdown has a value of 2 to indicate that lockdown is now over. From time unit 32 onwards lockdown has value 0 which indicates that there is no lockdown.

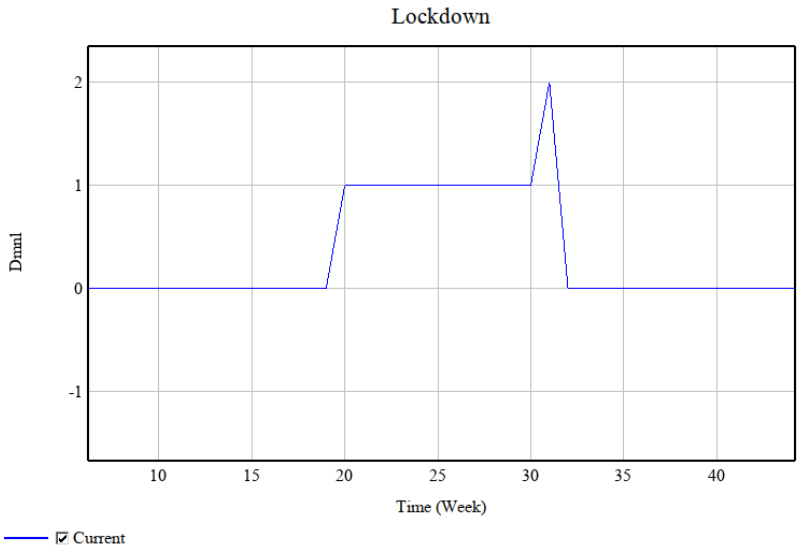

Fig. 15: Lockdown Simulation

ACTIVITIES & VEHICLES

As can be seen in fig. 16, Industrial, Tourism and Leisure, Wildlife conservation and drastically reduce during the lockdown period. Farming activities reduce but not to an extent to which other activities reduce. As a result, vehicles in use also reduce during the lockdown period. Fig. 17 depicts the graph of vehicles before, during and after the lockdown.

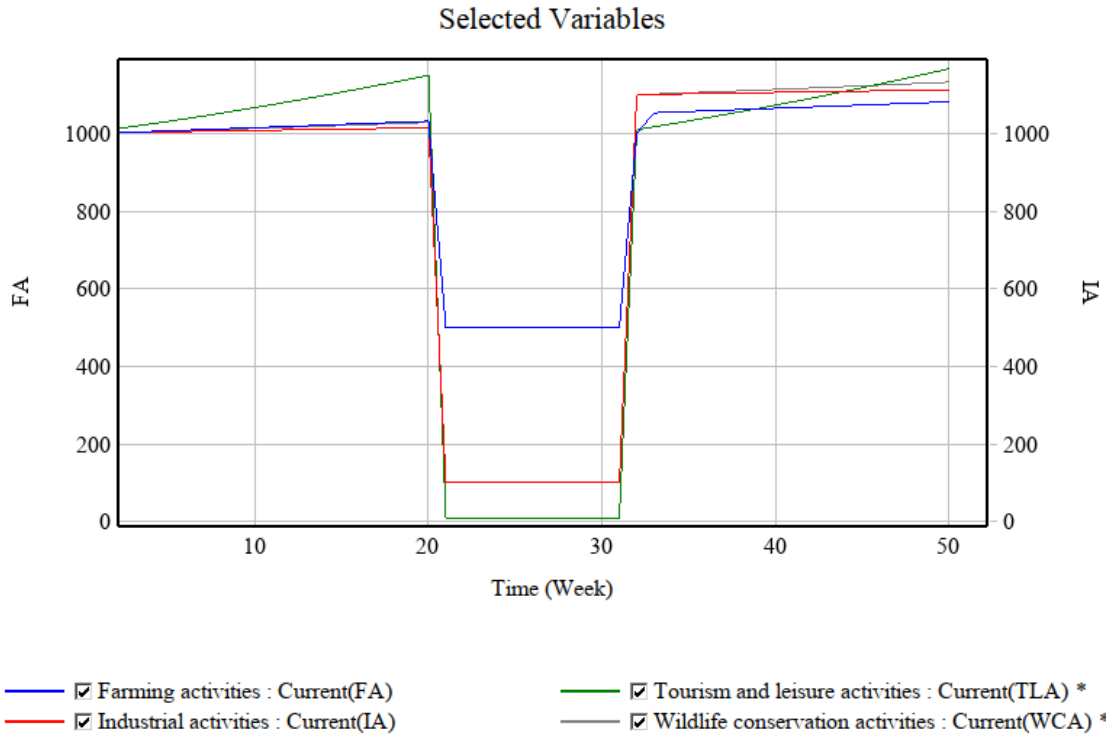

Fig. 16: Activities Simulation

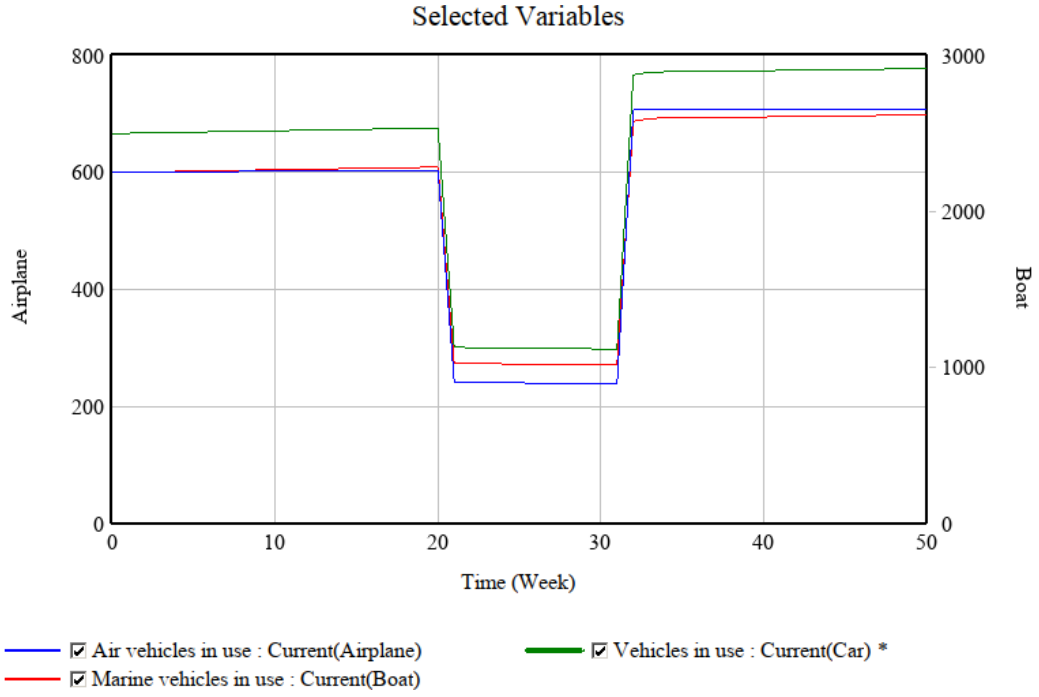

Fig. 17: Vehicles Simulation

POLLUTION

Pollution stocks like Air, Water, Noise and Soil are mainly affected by the different activities and vehicles in this model. There is a direct relationship between the activities and pollution. So, during the lockdown period, addition to these stocks reduces considerably. This behaviour can be seen in the simulation graph of Air pollution in fig. 20 , of Water pollution in fig. 19, of Noise pollution in fig. 21 and Soil pollution in fig. 18. Noise pollution reduces the most during the lockdown period. Water and Soil pollution also start dipping during the lockdown period but then start increasing gradually after the lockdown. Air pollution growth also reduces considerably during the lockdown. This dip in the levels indicates the lockdown provides a chance for the environment to "heal" itself.

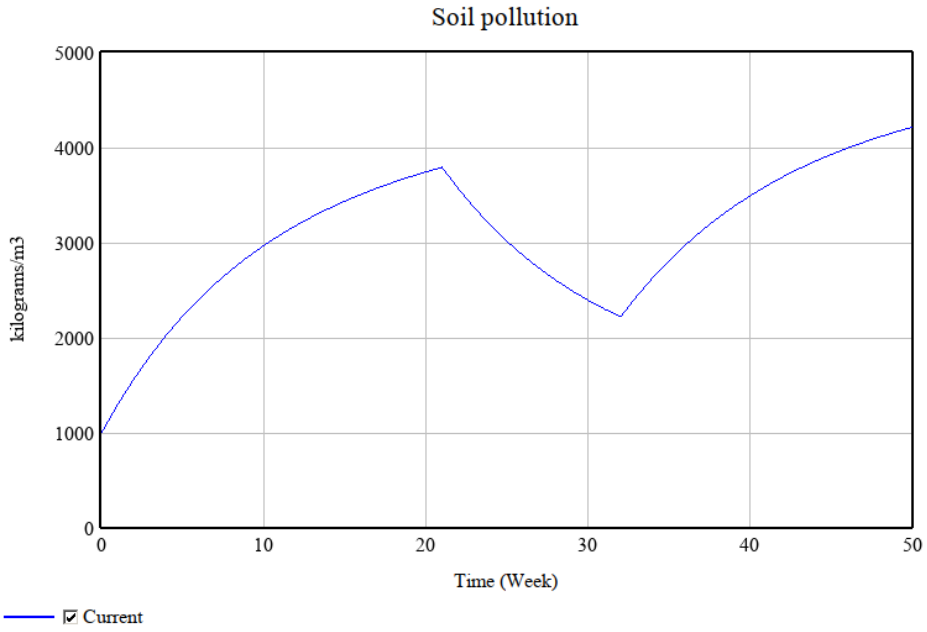

Fig. 18: Soil pollution Simulation

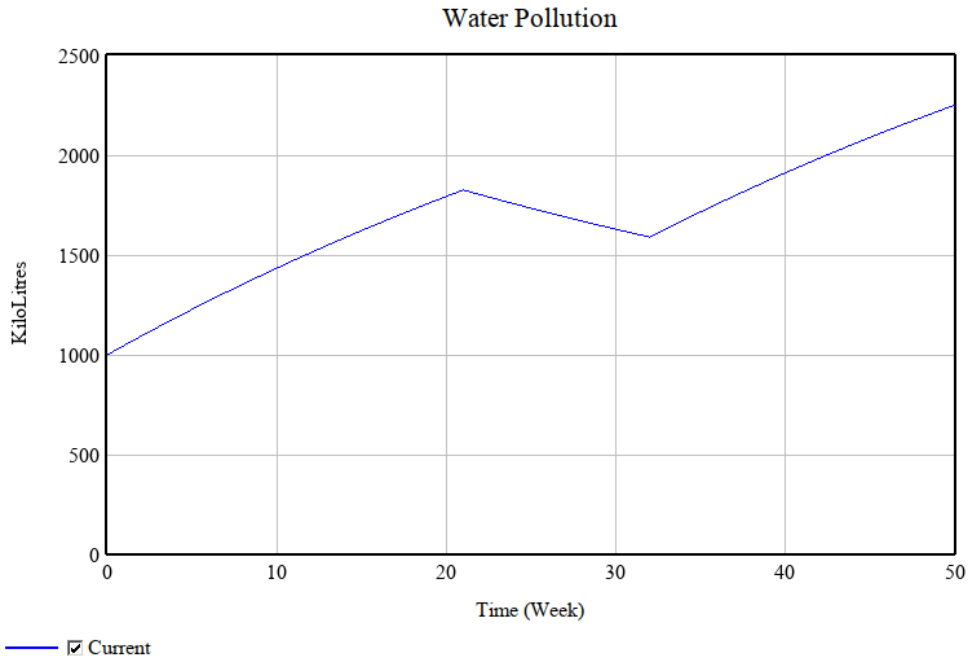

Fig 19. Water pollution simulation

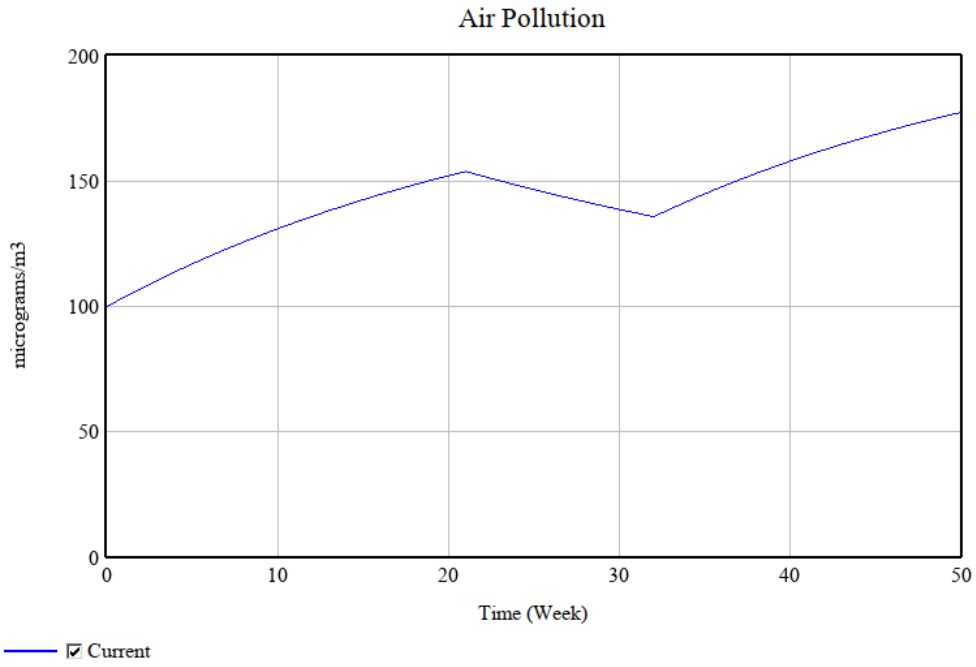

Fig 20. Air pollution Simulation

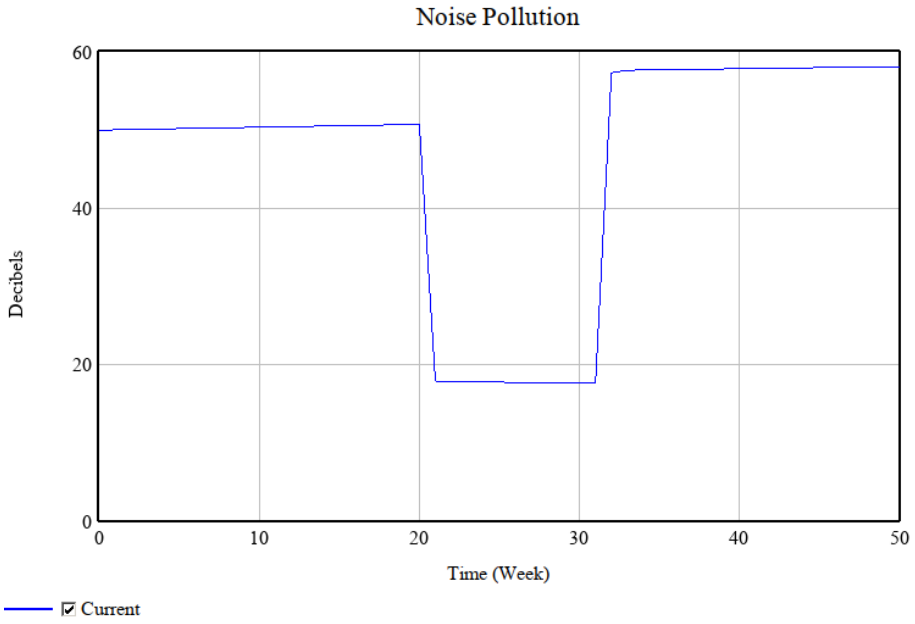

Fig 20. Noise pollution Simulation

HEALTH RISK

Health risk due to different pollutions (Air, Water, Soil and Noise) is expected to decrease during the lockdown since the pollution levels itself would go down. Also, people would stay at home and go out less. This behaviour is observed in the simulation graph of Health risk. During, the lockdown period health risk goes down considerably when compared to before and after lockdown.

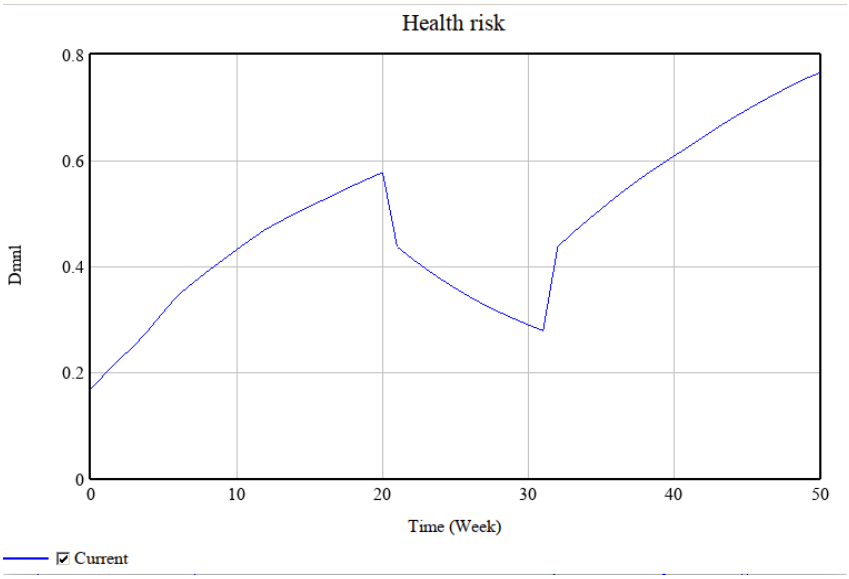

Fig 22: Health Risk Simulation

CONCLUSION

Thus we have modelled the effects of lockdown on the environment at a high level. Basic day-to-day activities are modelled as industrial activities (which includes manufacturing, automobile production etc.), Tourism and Leisure Activities, Wildlife conservation activities and Farming activities, Vehicles (Road, Marine and Air). Lockdown is modelled as a dimensionless variable which takes the value of 0 before and after the lockdown and a value of 1 during the lockdown, and 2 after the lockdown to simulate a realistic restart of the activities. During lockdown these activities reduce to the bare minimum and as a result, the vehicular activity also reduces. Pollution is modelled as comprising four different stocks viz. Air, Water, Noise and Soil. These stocks are affected by the day-to-day activities. On simulating the model, it is observed that the pollution levels reduce during the lockdown period as a result of the reduced activity and the environment around us “heals” itself. Due to the reduced pollution levels, health risk to humans also reduces.

FUTURE SCOPE

More often than not, restrictions are not completely lifted after the lockdown. Restrictions are eased up gradually to prevent sudden spread of the disease and to keep the situation in control. Lockdown has a lot of adverse side effects on various aspects of the society. Important services like health care facilities for common people become inaccessible. Economy of the country is severely affected resulting in a major setback to growth. Modelling these effects of lockdown would reveal a lot of interesting details. Also, one pollution stock (for eg. Air pollution) can be chosen and modelled in depth. Different factors affecting mostly that pollution stock should be studied with careful analysis of factors affecting the stock and it’s flows.

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