

Sub-Theme – IV



Design, Development, Modeling and
Planning for Sustainable living

Sub-Theme – 4

Design, Development, Modeling and Planning for Sustainable living

“All models are approximation... However, the approximate nature of the model must always be borne in mind.” – George Box

We have been consuming natural resources (i.e. materials or substances occurring in nature) since the beginning of industrial development at a faster rate than the planet is capable of regenerating them. Even today, in our day-to-day life we are over-using natural resources every year thereby posing threat to our future generation and livelihood. In fact, if natural resources consumption continues at the present rate then by 2030, two Earth-like planets will be required to generate enough resources to cater to our demands because the world population will consume every year two times more resources that the Earth can generate over the same period. So, it is essential to make every stakeholder aware to stop or reduce un-judicious use and unsustainable consumption of our natural wealth; else there will be serious depletion of resources and shrinkage of earth's carrying capacity.

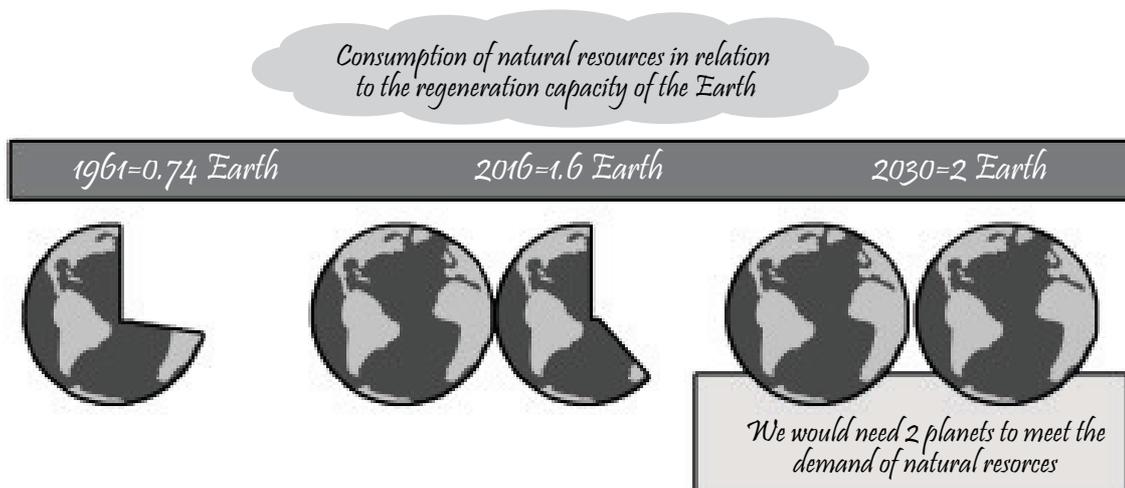


Fig. 4.1.Diagram showing Natural Resource Deficit

In other words, unwise exploitation of materials or substances occurring in nature for economic gain will drastically affect sustainable living of human population on Earth in the long run. Hence, there is a need to understand critically the causes and effects of resource utilisation. Such understanding is a prerequisite for effective and useful planning and management of available natural resources for bringing solutions to the identified problem(s) towards sustainability at local, state, national and global level.

Management of natural resource depends scientifically on reliable projections of future conditions (Modeling) to design, plan and implement desired actions towards sustainable living. Results from empirical studies, coupled with expertise and wisdom of people are essential components that are required for such planning, design and evaluation of management activities.

Modeling and design for planning resources is considered as most essential and need of the day. Virtually, Modeling helps to visualize the future scenario from the historical information/events/data that aid to design and plan the activities for sustainable future. In addition, it also assists to forecast/ predict consequences of our quality of life in case we continue to exploit the natural resources irrationally to meet our demands. This also enables us to evolve sustainable way(s) for resource planning, allocation and management leading towards sustainable lifestyles for all. Moreover, Modeling, design and planning also become useful for conservation and enhancement of natural resource base in its maximum pristine/pollution free levels, which are presently concerned by all globally. Nevertheless, it allows the stakeholders to understand the problem related to various biotic (vegetation, animal, human, etc.) and abiotic (soil, water, air, etc.) resources and their interrelationships. Outcome of these assessments can be applied for design and planning carrying capacity, threshold limits, environmental impacts, natural resource conservation and management and so on and so forth.

However, for better clarity and understanding, all the three aspects (Modeling, design, and planning) have been explained below.

(A) Modeling

Modeling is a systematic approach and projected representation of a system, phenomenon or situation through equation, graph, map and visuals. Model can help to understand a state or situation or phenomenon, not experienced or visualized at present, but there is possibility of it occurring in future. One of the purposes of any model is to enable an analyst/ user to *predict* the effect of changes in the concerned system or phenomenon. Such predictive Modeling is the process of using previous known results to create a model that can be used to forecast future outcomes. But, a model, on one hand, should be a close approximation to the real system. On the other hand, it should *not* be very complex to understand and unable to do experiment using it. So, *a good model is one that keeps balance between realism and simplicity*. The important issue in Modeling is its validity. Nevertheless, there are various types of models all of which do not come under the ambit of NCSC. Hence, only four types viz. physical, schematic, conceptual, and mathematical models have been described, in nutshell, below.

Physical model

It is a smaller or larger physical copy of an object. The object being modelled may be small (e.g., an atom) or large (e.g., Solar System). In other words, the physical models are smaller and simpler representations of the thing being studied (viz., a globe or a map). The structure of the model and the object it represents need *be similar* in the sense that one resembles the other. But in such cases, the *scale* is the most important characteristic to be followed accurately.

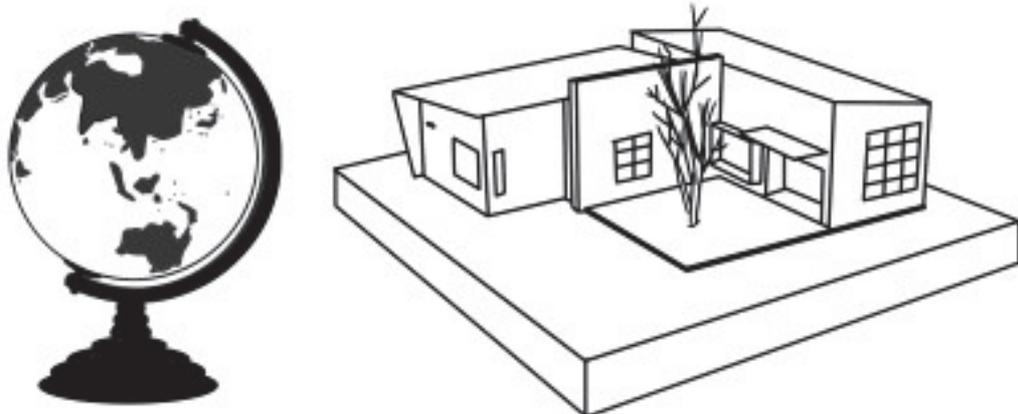


Fig.-4.2. Differences Between Model & Prototype

Box-4.1

Reductionist approach of Modeling:

The reductionist character of science and scientific Modeling means that however sophisticated a model may be, it is still a simplification of reality. The figure below schematically illustrates how the real world is reduced from a perfect sphere to an ‘imperfect’ one, i.e. a cube, and this cube is finally sub-divided into individual domains, separated by interfaces. Through reduction and decomposition scientists try to disclose the secrets encountered in their own domain and to understand the ‘grammar’ according to which the real world behaves. Once this grammar is understood, scientists and engineers are able to create their own alternative world. This process has, in the end, resulted in our modern built environment. In spite of being no more than an approximation of reality, models and the use of them have become the new vehicle to ‘manipulate’ reality and design a new technology-based society.

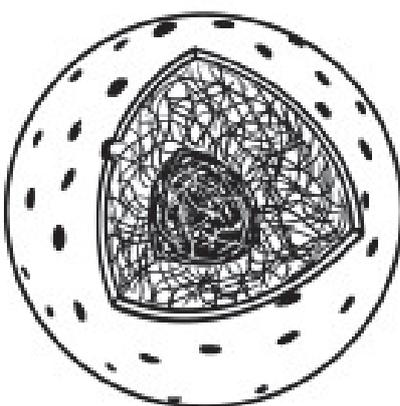
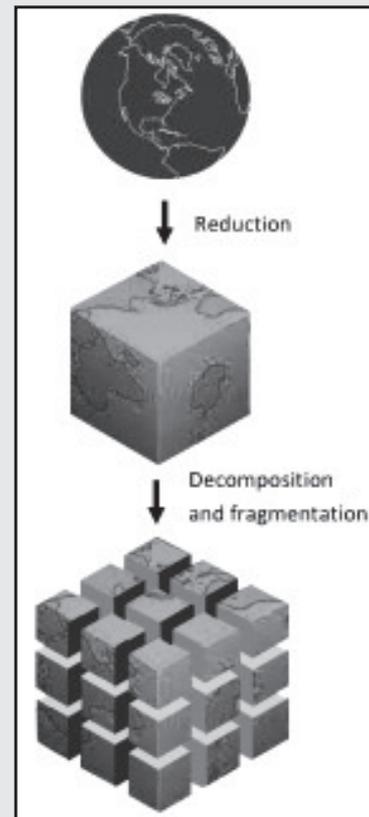


Fig. 4.3. Schematic model of a typical eukaryotic interphase nucleus

Schematic Model

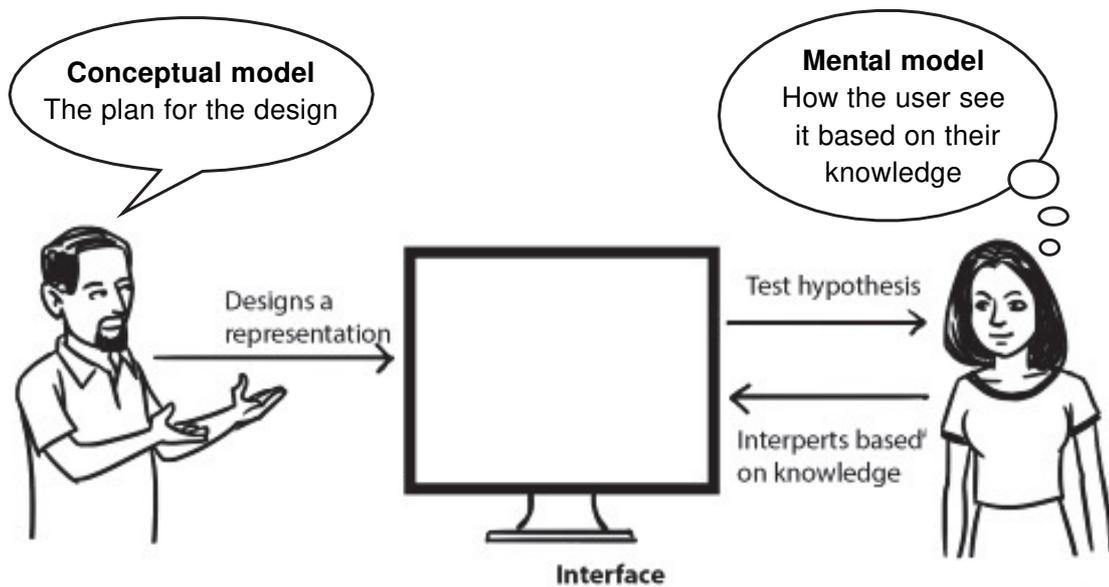
Schematic models are more abstract than physical models. While they do have some visual correspondence with reality, they look much less like the physical reality they represent. Graphs and charts are schematic models that provide pictorial representations of mathematical relationships. Pie charts, bar charts, and histograms are all models of some real situations, but they really bear no physical resemblance to anything. Diagrams, drawings, and blueprints also are versions of schematic model.

Differences Between Model & Prototype

Sl.No.	Physical Model	Prototype
1	Not necessarily functional (don't need to work)	Is fully functional, but not fault-proof.
2	Can be to any scale (usually smaller but can also be of the original size or bigger).	Is an actual version of the intended product (constructed in scale).
3	Used for Display or/and visual Demonstration of product.	Used for performance evaluation and further improvement of product.
4	May consist of only the exterior of the object/product it replicates.	Contains complete interior and exterior.
5	Relatively cheap to manufacture.	Is relatively expensive to produce.

Conceptual models

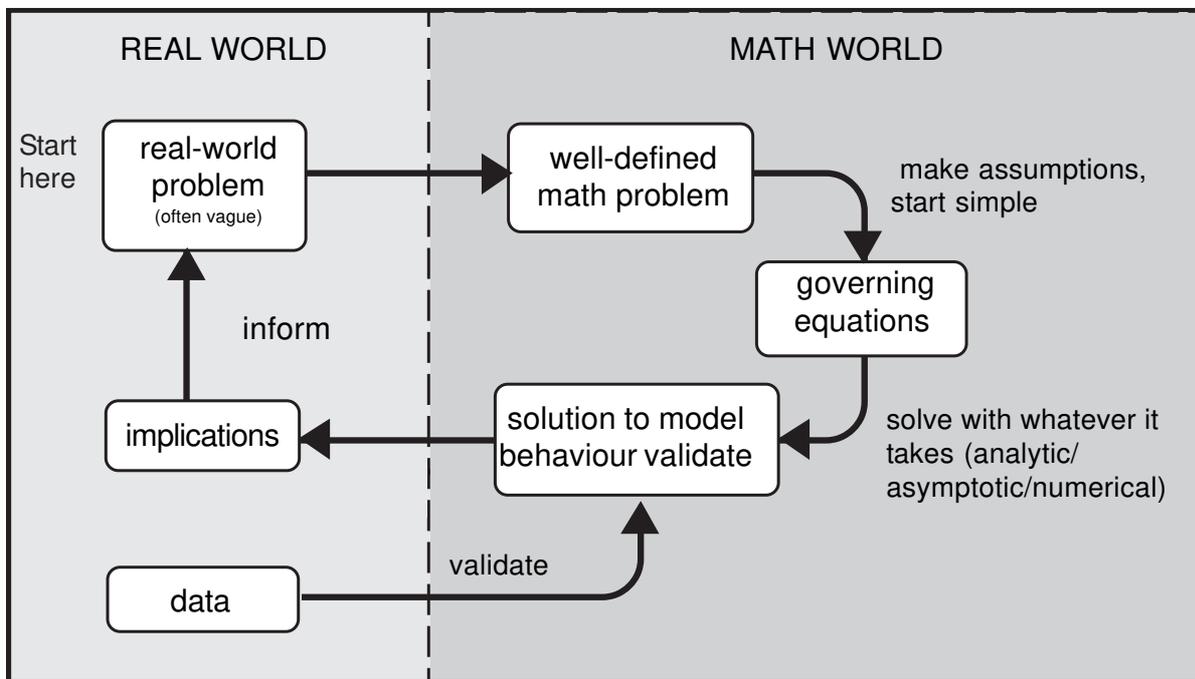
Conceptual models tie together many ideas to explain a phenomenon or event. It is representations of a system, made of the composition of concepts which are used to help people know and understand a subject that the model represents. It is also a set of concepts. A conceptual model's primary objective is to convey the fundamental principles and basic functionality of the system which it represents. A conceptual model, when implemented properly, should satisfy its fundamental objectives. The conceptual model plays an important role in the overall system development life cycle.



Mathematical Model

Mathematical models are perhaps the most abstract of the four classifications. These models *do not* look like their real-life counterparts at all. Mathematical models are built using numbers and symbols that can be transformed into functions, equations, and formulas.

It is a description of a system using mathematical concepts and language. The *process* of developing a mathematical model is termed as mathematical Modeling. These are used in the natural sciences (e.g., physics, biology, earth science, chemistry, etc), and engineering disciplines (e.g., computer science, electrical engineering etc.), Health science (Spread of disease, etc.) as well as in social sciences (viz., economics, psychology, sociology, political science, etc.). However, Mathematical Modeling is the process of using various mathematical structures - graphs, equations, diagrams, scatter plots, tree diagrams, etc., to represent real situations. Following is the flow chart usually followed for such Modeling:



MATH MODELING FLOWCHART

A mathematical model can be used for a number of different reasons:

- Developing scientific understanding - through quantitative expression of current knowledge of a system
- Supports in examining the effect of changes in a system
- Aids in decision making

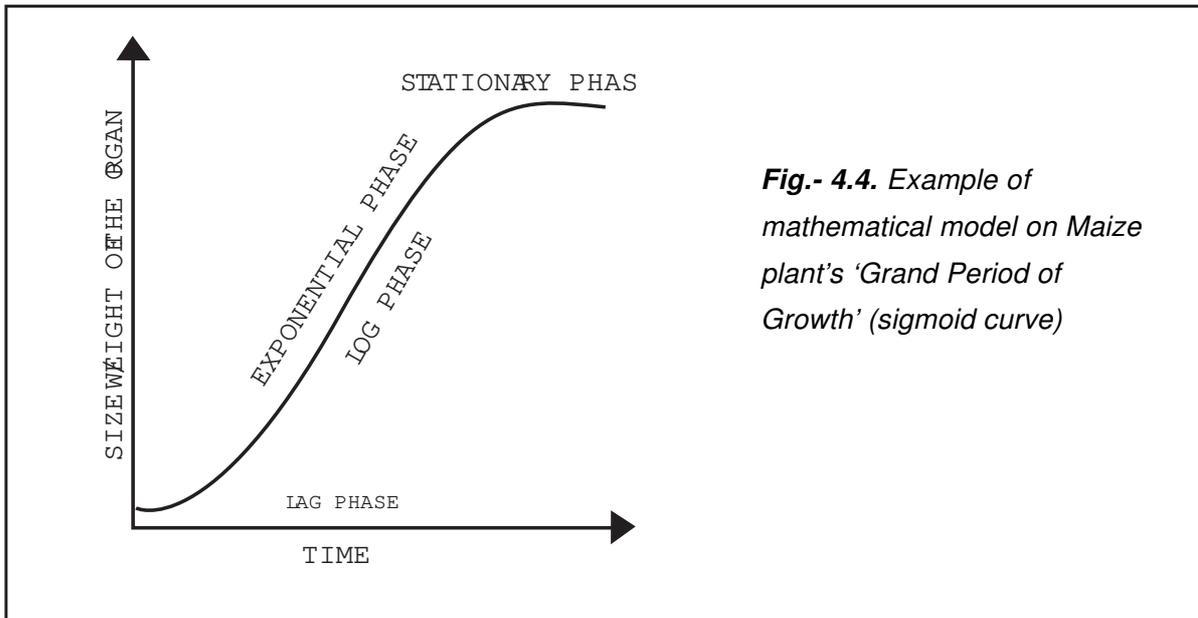


Fig.- 4.4. Example of mathematical model on Maize plant's 'Grand Period of Growth' (sigmoid curve)

(B) Design

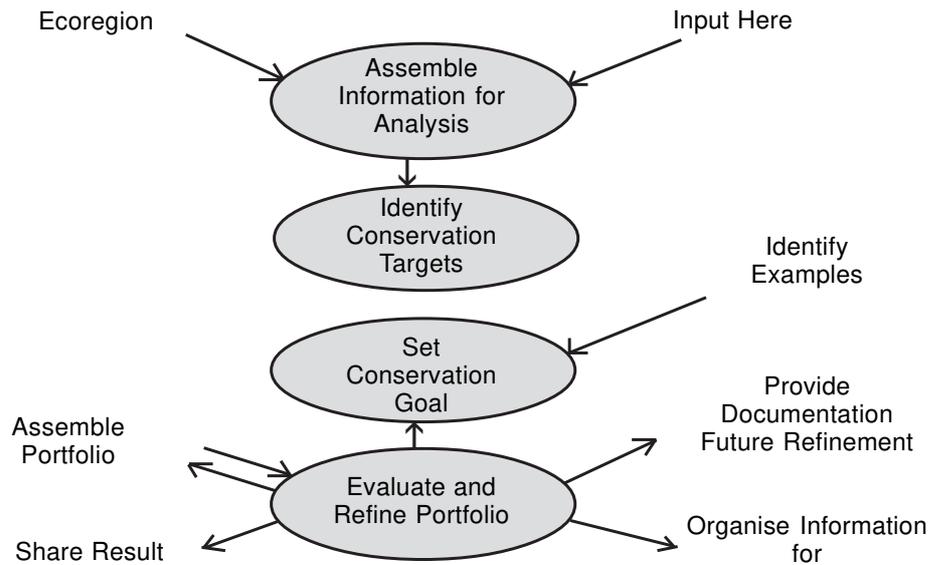
Design is an approach to give a shape /structure of an object/tools/gears/ assets to enhance / strengthen its functional efficiency, easy to handle/use/manage, minimize the use of material and energy, labour cost, along with aesthetic values.

Different principles of mathematics, physics, chemistry, biology etc., along with elements of art are used for designing any object/article. In context of sustainable living, it is focused on different day-to-day utilities, tools and gears, infrastructures which ultimately based on



the principle of minimum input use and maximum output. Use of minimum inputs from Earth's resources in the form of material and energy, minimization of waste and optimisation of its utility determines efficiency. Sustainable design seeks to reduce negative impacts on the environment, the health and comfort of the

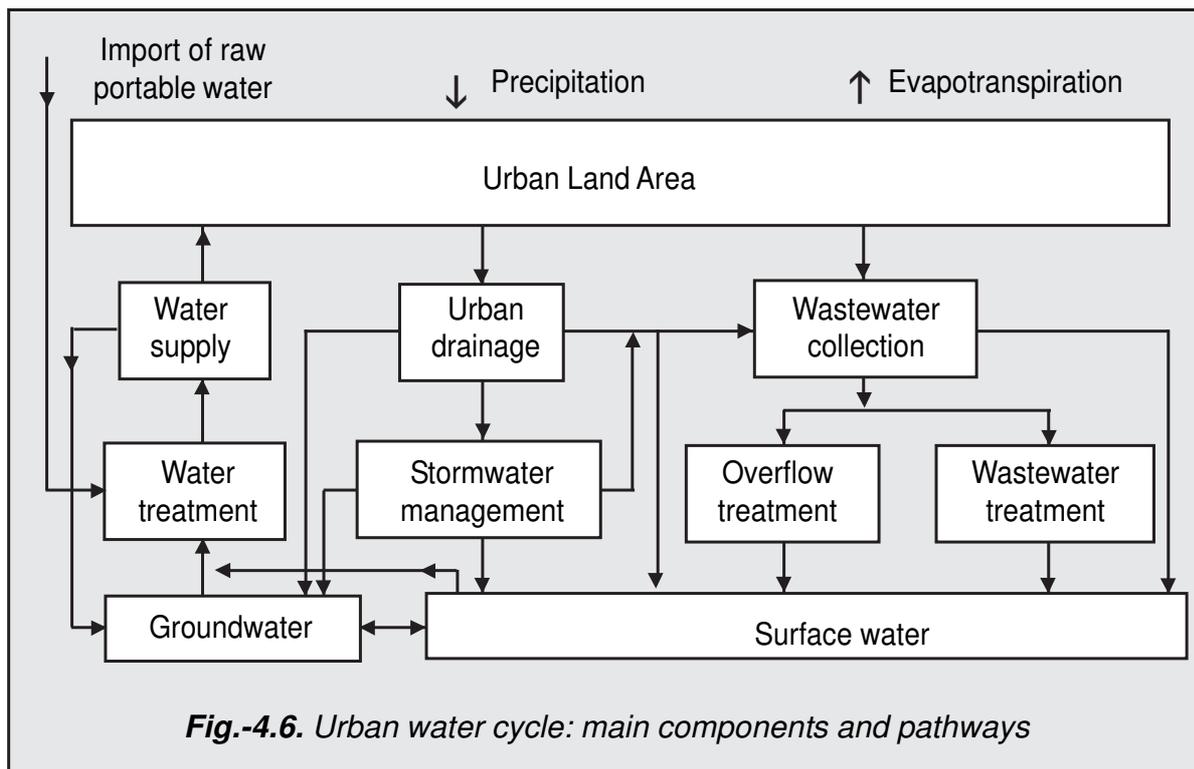
multiple levels from local to global, based on the need or demand. In recent past, planners and scientists are concerned over climate change, clean air and water, renewable energy and land use for the greater interest of sustainability and to develop strategies and practices for liveable and self-sustaining communities over long term. The flow chart below shows ecological communities in Eco regional plans.



Source: Anderson, M, Joseph Comer P, Grossman D, and Weakley S.A. 1999. *Guidelines for Representing Ecological Communities in Eco regional Conservation Plans.* The Nature Conservancy.

In fact, environmental and natural resource planning use balanced decision-making that takes into consideration the natural environment. The process combines protection of environmental resources with community goals. Natural resource planning and management deal with managing the way in which people and natural landscapes interact in rational ways. It brings together land use planning, water management, biodiversity conservation, and the future sustainability of industries/ activities like agriculture, mining, tourism, fisheries, forestry and many more.





Following are few examples of overall plan for sustainable living:

- Carrying Capacity
 - The maximum population that can be sustained by a given environment/world
- Population Growth rates
 - Family Planning
 - Education
 - Women's Status
- Housing etc.

Box- 4.1

Elements of smart and sustainable housing

• **Social sustainability:**

Safety + security + universal design = social sustainability.

• **Environmental sustainability:**

Water efficiency + waste efficiency + energy efficiency = environmental sustainability.

• **Economic sustainability:**

Cost-efficiency + peace of mind + higher resale value = economic sustainability.

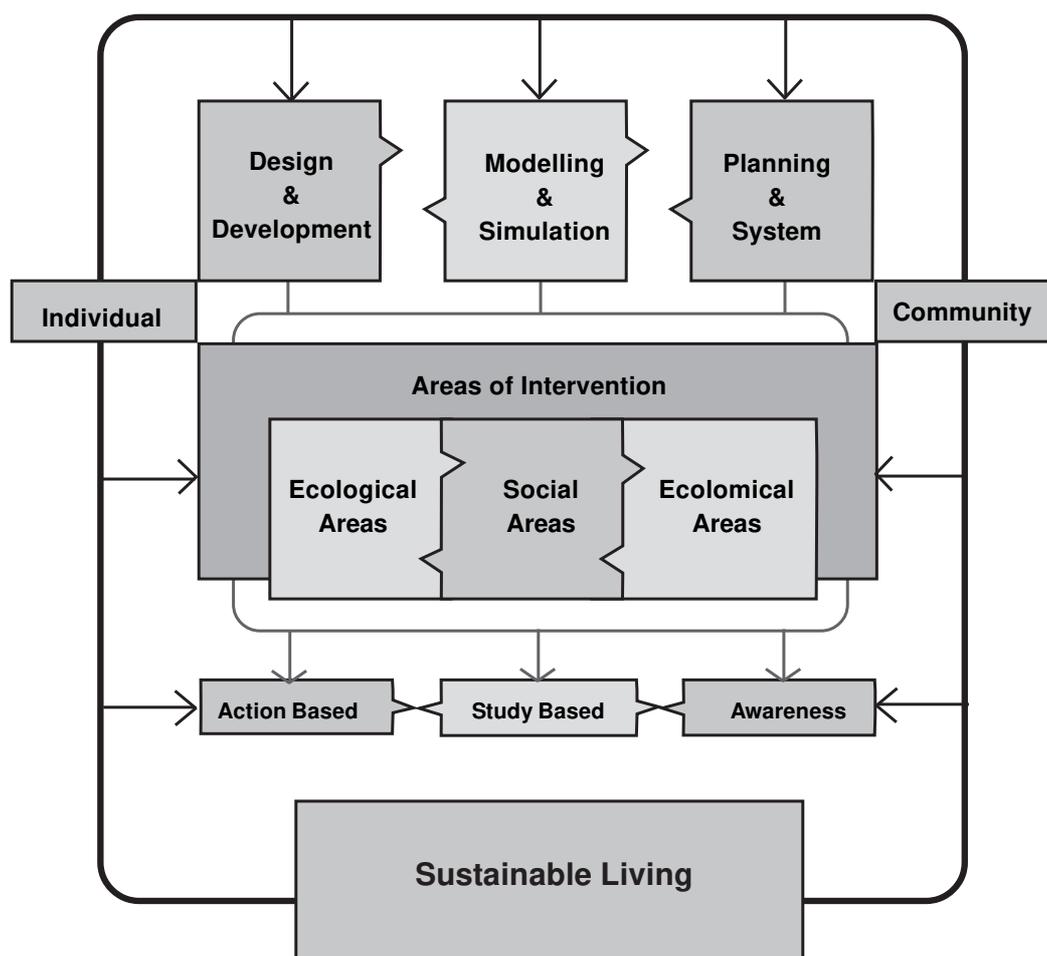


Fig. 4.7: Summarised flowchart

Scope for Doing Project

The sub-theme has scope of undertaking projects in wider areas related to natural resources, water and air, environment, plants, animals (both macro & micro), and human being, etc, and also the interactions. They can easily study the chosen problem using simple mathematical laws of *Algebra, Trigonometry, Geometry, Coordinate Geometry, Solid Geometry, Differential calculus*, etc. However, considering various limitations for the children of different socio-economic and geographic conditions, it is advised to take up small and unique project in any of the areas described above. In table below, the probable focus areas have been shown for convenience of the children. Further the focused areas have been presented in the following table:

Table-4.7: Focus Areas

Approach/Focus	Modeling based	System and planning based	Design and development focussed
Ecological	Environment (Land, soil, water, Air, etc.)	Natural Resources	Bio mimicry
	Biodiversity		
	Habitat/Ecosystem -Terrestrial - Aquatic	-Land use -Land cover	
	Climate and Climate change		
	Disaster mapping	Disaster management	Design for disaster prone areas
Social	Construction and development Health and Diseases	Habitat planning Energy &Sustainability	Product design Habitat design - - Construction - Structure - Environment
		Human Capacity and Flow	Design for special need
Economic	Agriculture Fisheries	Production and consumption	
	Animal Husbandry		
		Policy development	

Box – 4.2.Few Examples of Design using Biomimicry:

Humans have always looked to nature for inspiration to solve problems. Leonardo da Vinci applied biomimicry to the study of birds in the hope of enabling human flight. He very closely observed the anatomy and flight of birds, and



made numerous notes and sketches of his observations and countless sketches of proposed “flying machines”. Although he was not successful with his own flying machine, his ideas lived on and were the source of inspiration for the Wright Brothers, who were also inspired by their observations of pigeons in flight. They finally did succeed in creating and flying the first airplane in 1903. Leonardo’s design for a flying machine, c. 1488, inspired by birds in flight. Pigeons also influenced the Wright Brothers’ design for the first airplane.

Recent developments

- Photovoltaic systems, which harvest solar energy, are a first step at mimicking the way leaf harvests energy. Research is underway to create solar cells that more closely resemble nature. These cells are water-gel-based—essentially artificial leaves—that couple plant chlorophyll with carbon materials, ultimately resulting in a more flexible and cost-effective solar cell.

- The Thorny Devil, a desert lizard, gathers all the water it needs directly from rain, standing water, or from soil moisture, against gravity without using energy or a pumping device. Water is conveyed to the lizard’s mouth by capillary action through a circulatory system on the surface of its skin. This same concept is trying to be applied to passive collection and distribution systems of



naturally distilled water which would reduce the energy consumed in collecting and transporting water by pump action (e.g., to the tops of buildings) and will provide other inexpensive technological solutions such as managing heat through evaporative cooling systems, and protecting structures from fire through on-demand water barriers.

Model Projects

Project – 1: Land use change and its impact on natural and cultural landscape

Background

Land use change is a process by which human activities transform the natural landscape, referring to how land has been used, usually the purpose. Land use changes are often nonlinear and sometimes may be causing multi-dimensional impacts to the environment. Therefore, land use changes need assessment, and it is also possible to model future conditions as per assumptions, to ensure sustainable conditions.

Objectives

1. To assess the land use changes over a time period
2. To conduct field level survey to verify and document land use changes.
3. To quantify changes in land use.

Methodology

To conduct the study, Step – by-step procedure, as given below, is to be followed.

1. Identify the area of study, with a natural or manmade boundary, that can be easily identifiable in the Google Earth image.
2. Save the images of the area from Google Earth for the available years
3. Demarcate land use classes for each year like forest, agricultural land, built up area, water body etc.
4. Find out the area of each classes in every year (using Google Earth; area tool)
5. Tabulate the data and calculate percentages
6. Calculate percentage changes for each category

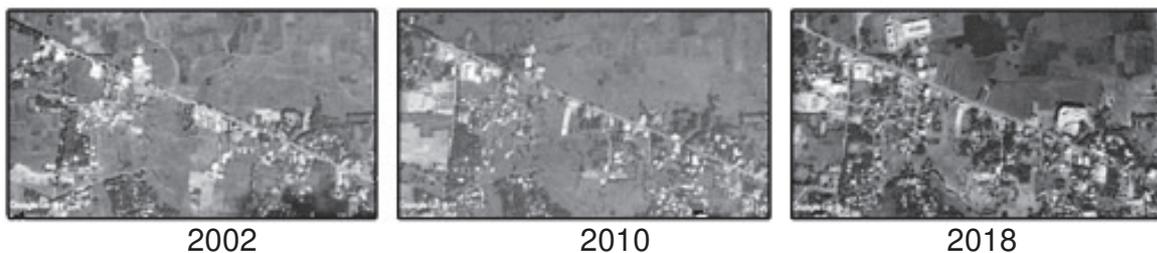


Fig.-4.1.1. Satellite images for three different years (from Google map)

Table-4.1.1: Areas under different land uses, calculated from the maps

Sl. No	Land useClasses	Area, km ²			Area %			Change in area %		
		2002	2010	2018	2002	2010	2018	2002-2010	2010-2018	2002- 2018
1	Forest	0	0	0	0	0	0	0	0	0
2	Agricultural land	18	17	15	72	68	60	-4	-8	-12
3	Built-up area	6	7	9	24	28	36	+4	+8	+12
4	Waterbody	1	1	1	4	4	4	0	0	0
	Total	25	25	25	100	100	100	0	0	0

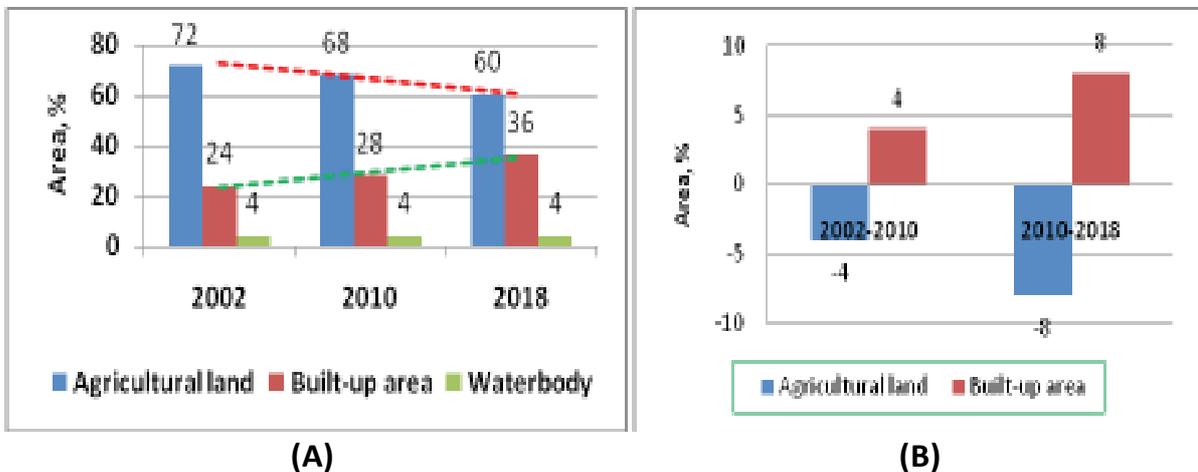


Fig.4.1.2: Decadal changes in land areas (in percentage) in two different decades (A) and changes during two decades (B)

Expected Results

1. Major land use categories in the area
2. Extent of each land use in different years
3. Changes in land use during these years
4. Decline or increase in respective land use categories with time

Expected outcomes

1. Use of free satellite image data for local understanding
2. Changes in pattern of land use over time

Project- 2: Modeling Alien Invasive Plant Species for Management

Background

Many invasive alien plant species which are non-native, spread and interfere in a new ecosystem by posing a serious threat to the native biodiversity, leading to several irreparable losses including economic losses. Invasive species don't allow local species to grow and pose obstruction to wildlife movement. Species like *Lantana*, that grows extensively, leading to degradation and destruction of the biodiversity. Ecological equilibrium of an ecosystem can be maintained only by balancing local floral and faunal population. However, Ecologists are of the view that the removal of the alien species should be in a phased manner with subsequent planting of the native floral/ faunal species in order to improve the biodiversity.



Lantana

Since a significant amount of man power and money is required for control and management measures for alien invasive species, it is necessary to define the area of intervention, estimation of populations and prediction of future situations if the process of invasion continues. For the sake of the study let us consider the *Parthenium hysterophorus* as a plant to study.

Hypothesis

The alien plant species will grow widely in a few decades that will affect the growth of local plant species.

Objective

For the purpose, following objectives have been decided:

1. To identify the potential alien invasive species spread in the locality and estimate the frequency of its occurrence in time scale.
2. To develop a mathematical model to predict its over crowdedness in comparison to one of the major native species

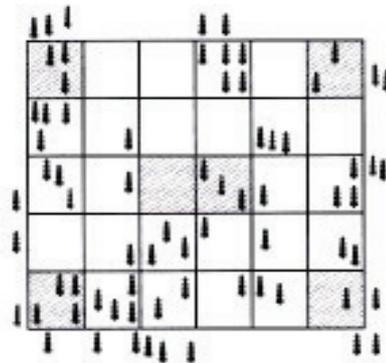
Methodology

The methodology comprises of three segments- experimentation, development of model, and validation of model. All the three segments have been explained below.

(I) **Experimentation**

Step – 1: Select an area, big enough to include maximum number of species to be studied in your locality.

Step – 2: Identify the species to be considered for the study. Here, one alien (Species - A) and one native/ local (Species - B) species have been considered.



Step – 3: Using grid methods find out the number of species in each of the grids as shown below-

Note: Follow the method given in your text book.

However, prior to beginning, prepare the table shown below in order to record the data in the field. Then, calculate Frequency percentage with the formula given below

$$\text{Frequency} = \frac{[(\text{Number of sampling units in which the species occurs}) / (\text{Total number of sampling units employed for the study})] \times 100}{}$$

It is expressed in percentage (%) and denoted as 'F'.

Table – 4.2.1. Species-wise number of plants in the six grids and their frequencies

Species	Grids						Total Number (N)	Frequency % [(N/6)x100]
	I	II	III	IV	V	VI		
Species - A	67	55	62	59	62	44	349	58.1
Species- B	38	47	33	40	33	54	245	40.8

Step – 4: Take out some plant sample and prepare a Herbarium.

Step – 5: Before meeting the villagers, prepare a table as shown below-

Respondents	Frequency, %				
	2018	2017	2016	2015	2010*
1					
2					
3					

*Indicates, may be, the year when it was identified first

Step – 6: Select few elderly dwellers of the locality who live on land and ask them pre-designed questions about the plant species chosen for the study. A few sample questions are given in the box below-

Step – 7: Put the information gathered from each individual respondent in the table as shown below. Here some hypothetical data have been considered.

Table-4.2.2. Frequency of occurrence of **Species – A**, by year, as gathered from survey

Respondents	Frequency, %				
	2018	2017	2016	2015	2010*
1	50	45	40	45	5
2	55	60	50	40	5
3	60	50	45	40	10
Average	55.0	51.7	45.0	41.7	6.7

Table-4.2.3. Frequency of occurrence of **Species – B**, by year, as gathered from survey

Respondents	Frequency, %				
	2018	2017	2016	2015	2010*
1	40	45	45	50	80
2	45	50	55	55	80
3	45	50	55	55	75
Average	43.3	48.3	51.7	53.3	78.3

**Repeat the process for all the considered species separately for your clarity in understanding.*

Few sample questions:

Q1: Are you acquainted with these plants?

Q2: Do you agree that these are affecting growth of local plants?

Q3: If yes, how do you think are they affecting their growth?

Q4: How many years ago these alien species were found?

Q5: Can you say approximately the amount of these species found by years, in percentage? (This will be the information on frequency)

Q7: How do you think we can control the growth of these plants? Do you know any techniques? Q8: Do you know of any other non-invasive species in your locality?

NB: showing the calculated values ask question to answer with relation to that to arrive at nearly correct values.

- *These are only samples; but, more question pertinent to your hypothesis may be asked.*

(II) **Model Development**

Caution: Development of such model needs long-term data, usually for 2-3 decades, but for children to understand, a short-term data has been considered. Please remember, more the time span, more will be the precision.

So, in quest of developing a model, simple mathematical relation has been tried. The Step – wise method followed has been described below:

Step – 1: Convert the years of study in number as mentioned below:

Table-3: Assigning number to the corresponding years

2010	2015	2016	2017	2018	2019
-9	-4	-3	-2	-1	0

[Note: The current year (2019) of study when the data are recorded in the field to be considered as zero (0) and the years before the year 2019 (i.e. year in which the study has been undertaken in the field) to be considered as negative (-) and the years beyond 2019 as positive (+)].

Step – 2: Put the values from tables - 4.2.1, 4.2.2 & 4.2.3

Table-4.2.4. Year-wise frequency of Species-A

Plant Species	2010	2015	2016	2017	2018	2019
	-9	-4	-3	-2	-1	0
A	6.7	41.7	45.0	51.7	55.0	58.1
B	78.3	53.3	51.7	48.3	43.3	40.8

Step – 3. Calculate the relationship of frequency with the number of years with Pearson correlation coefficient value (See the method of calculation in the Box –I).

Step – 4. Plot the data of Table-4 in a millimetre graph paper with the number of year (T) and frequency (F) in x and y axis respectively. Then draw the best-fitted straight line, as shown below.

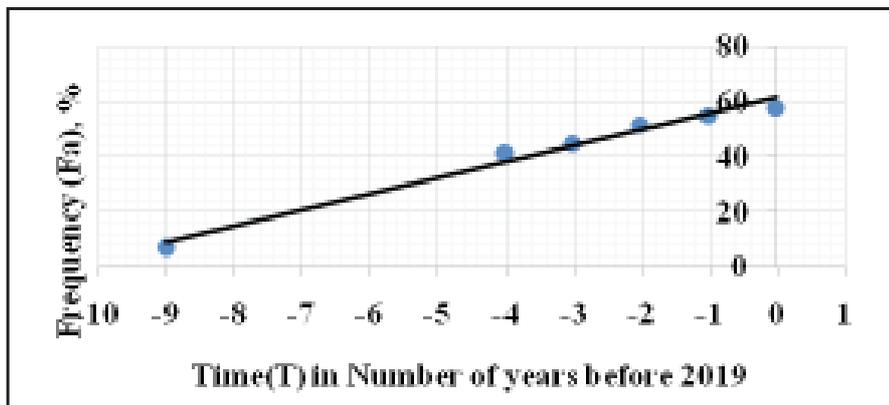


Fig.-4.2.1. Relationship between frequency of Species-A with number of years

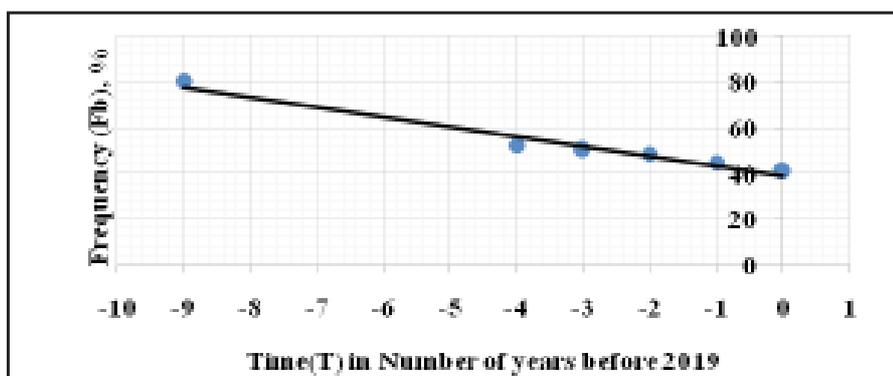


Fig.-4.2.2. Relationship between frequency of Species-B with number of years

Step– 5. Using geometric, algebraic or trigonometric method find out the values of ‘m’ and ‘c’ of the straight line equation ($y = mx + c$) from the above graph (Fig.-1).

Note: The equation of the line making an intercept c on y-axis and having slope m is given by $y=mx+c$. Note that the value of c will be positive or negative as the intercept is made on the positive or negative side of the y-axis, respectively. Follow the method that has been taught in the school.

Step – 6. Note down the values in the table as shown below-

Table-4.2.5. Correlation values (between F and T) and intercepts and slopes of the lines

PlantSpecies	Intercept & Slope of the line		Correlation value (r)
	c	m	
A	61.54	5.85	0.98
B	39.20	-4.29	0.97

Step – 7. Explain about nature of relationship as well as strength between the two variables – F & T.

Step – 8. Write down the equations, which are the individual models of two plant species.

$$F_a = 5.85 T_a + 61.54 \dots\dots\dots (i)$$

$$F_b = -4.29 T_b + 39.20 \dots\dots\dots (ii)$$

Where, F is percentage frequency and T is the time in the number of years. Subscripts ‘a’ and ‘b’ indicate the species A and B respectively.

(III) Validation of Model

Every model developed is essentially needed to be validated by projecting the estimated values for the purpose of planning, action and development. Therefore, an attempt has been made here to validate the models calculating estimated frequencies of both the plant species. The steps followed has been explained below-

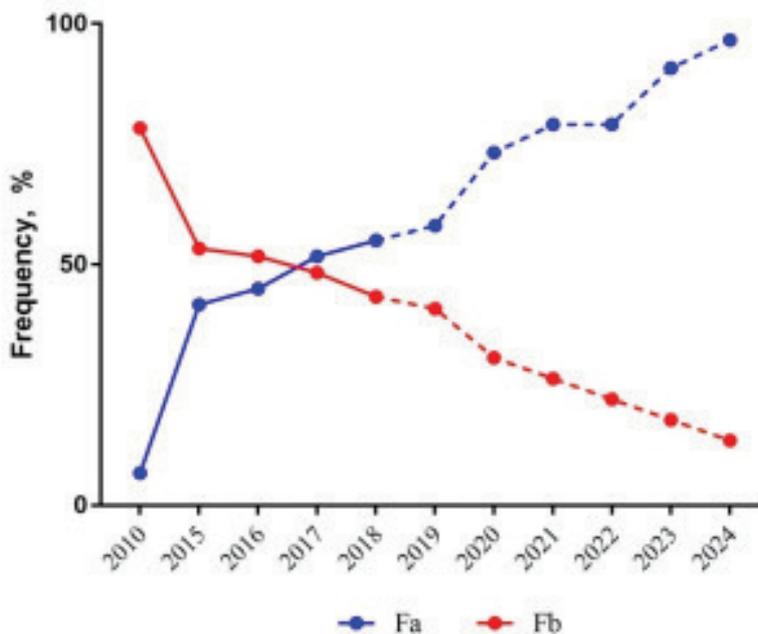
Step – 1: Put the values against T_a and T_b for the years beyond 2019, as shown below, and calculate the predicted values of F_a and F_b .

Step –2: Present the values in the tabular form as has been shown in Table-4.2.6.

Table-4.2.6. Estimated frequencies of the two plant species using linear model
 Step – 3: Put the values of F_a and F_b against the years you want to predict (here it is from 2020 – 2025). Draw the curves for both the species. Finally, join every point with the distance bars.

Particulars	2019	2020	2021	2022	2023	2024
F_a	58.1	73.24	79.09	79.09	90.79	96.64
F_b	40.8	30.62	26.33	22.04	17.75	13.46

Fig.-4.2.3.The predicted population frequencies of both the plant species, 'A' and 'B'. The dotted lines are the extrapolated data.



Inference

It appears from the figure- 3 that the distance between the species has been increasing at an alarming rate since 2018 or even prior to that. With the progress of time the population of alien species will supersede the population of the native species under consideration. So, it will deteriorate the biodiversity as well as the ecosystem in the long run. It is not unlikely that the native species will be extinct in next few years.

Hence, hypothesis under consideration is accepted.

Project-3: Computing Carrying Capacity and Population Prediction of an Organism Grown Under Resource-Stress Conditions

Background

The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. Ecosystems cannot exceed their carrying capacity for a long span of time. In situations where the population density of a given species exceeds the ecosystem's carrying capacity, **the species will deplete its source of food, water or other necessities**. Soon, the population will start dying of. A population can only grow until it reaches the carrying capacity of the environment. At that point, resources will not be sufficient to allow it to continue to grow over the long-term.

For the purpose of the study, the earthworm has been chosen as a test animal.

Hypothesis

Availability of food and environmental quality influence reproduction and population of earthworm.

Objectives

1. To examine the influence of different types of feed on population growth
2. To find out carrying capacity
3. To predict population under each types of feed provided

[Note: Before you begin your project, do a little background research on earthworms, their diet, **biology**, and how to properly prepare and care for them in the bins. Follow the standard procedure in your text book or in other sources.]

Experimental Procedure

Step – 1. Select three types of feed. It may be-

- (i) Finely crushed egg shells
- (ii) Fruit pieces with peels
- (iii) Vegetable pieces and skins

- (iv) Grass clippings and dry leaves
- (v) Moist shredded newspaper (avoid coloured pages)
- (vi) Cereal and grains
- (vii) A mixture of any of the above
- (viii) Any other materials of your choice

Step– 2: Decide on the type of food to be added. All the treatments should be given same kind of feed; but the amount will vary treatment-wise. Here let's use the following treatments with 'X' type of feed -

Plot-A: X gm

Plot-B: $\frac{2}{3}$ rd X

Plot-C: $\frac{1}{2}$ of X

Step – 3: Collect nine plastic or earthen pots of at least of 30 cm diameter, if not more. Of these, make three pots in one batch and thus there will be three batches having three pots in each. Make drainage holes in each pot.

Step – 4: Label the three batches as 'A', 'B' and 'C'. You may go further by labelling each batches as A_1, A_2, A_3, \dots and like this B & C.

Step – 5: Collect soil from the field

Step – 6: Place soil in each pot to about three-fourths of the way up. Sprinkle the soil with some water so that it is damp, but not soaking wet and pat the soil down into the pot a bit. Add more moist soil, if necessary, to bring the level back up to three-fourths.

Step – 7: Collect locally available earthworm. Worms of similar size and length should be chosen as far as possible.

Step – 8: Divide the worm in nine groups. Count and weigh the groups.

Step – 9: Gently put the worms in each of the cups on the soil of the pot. Add more moist soil on top of the worms so that the soil level reaches about 5 cm (2 inches) from the top edge of the pot.

Step – 10: Cover all the pots with moist newspaper.

Step – 11: Wrap each pot in a dark plastic bag. Be sure to make some small air holes on the top of the bags.

Note: *Ensure all pots experience similar conditions like temperature, humidity, etc.*

- Step – 12: Place the pots in a cool place,
- Step – 13: Weigh and record, in grams, the mass of each type of food before you put it in the pot.
- Step – 14: Place a layer of food in the respective pots under the newspaper. Cover the food with the moist newspaper.
- Step – 15: Sprinkle some water on top, if needed, to keep the food, soil, and newspaper moist.
- Step – 16: Cover the pots with black plastic bags; be sure the air holes are still at the top of the pot.
- Step – 17: Measure the acidity (pH), nitrogen (N), phosphorus (P) and potassium (K), of the soil used for potting. This will be the initial data.
- Step – 18: Check the pots every 2–3 days, and add food and/or water if needed. Check if most of the food disappeared before adding a new batch of food.
- Step – 19: Record the amount of each addition of food and water. Also observe what does the food look like. Are there any changes in the surface or appearance of the soil? Look for deposits of worm casts (a mass of mud thrown up by a worm after it has passed through the worm’s body) on the surface.
- Step – 20: Prepare a data table, as shown below, for each pot to record what you do and observe. Include: Start date, initial number of worms, group mass of worms etc.

Table-4.3.1. Population characteristics before and after the experiment

Treatments	Initial Population		Final Population		Death,%
	By number	By weight, gm	By number	By Weight, gm	
A					
B					
C					

Step – 20: Measure the acidity (pH), nitrogen (N), phosphorus (P) and potassium (K) of the soil used for potting. This will be the final data. Record the soil analysis results for each pot in your lab notebook. Take average of all the components.

Results

(A) Worm Count and Soil Analysis

1. After two months (a longer period may be even better), count and record the number of worms and their group mass in each of the pots. Do this by dumping out the soil from the pot carefully on a large tray or pan that is lined with newspaper. Gently push away the soil to find the worms.
2. Weigh an empty paper cup on the weighing scale and record the cup's mass (W1) in grams. Add the worms to the cup and weigh it (W2) and also count them.
3. Record the number of worms you find in each pot in your table like Table-4.3.1.
4. Calculate the group mass of the worms by taking the difference of W2 – W1 and record that in your table.
5. Calculate Carrying Capacity for each of the pots. The calculation has been described below:

(B) Calculation of Carrying capacity

Earthworm is our test animal. Let, all the treatments are inoculated with 10 numbers of earthworms, which is denoted as P_0 . So, after 2 months, the period of experiment, the change in population, denoted as P_1 , will increased by say 6,4 and 2. On the other hand the death rates are 0, 2 and 4. Table 4.3.2 shows the calculated values for f (fecundity), d (death) and r (intrinsic growth).

Table- 4.3.2. Change in population, fecundity and death of the worms after two months

Treatments	P_0	P_1	Change in population ($P_1 - P_0$)	Death in number (D)	d- value ($D/ P_0 = D/10$)	Fecundity (f)	(f - d)	r = (1+f-d)
A	10	16.1	6.1	0	0	0.61	0.61	1.61
B	10	14.4	4.4	2.3	0.23	0.44	0.21	1.21
C	10	12.6	2.6	2.8	0.28	0.26	0.02	1.02

Therefore, intrinsic growth rate (r) will be-

$$r = 1 + (f - d).$$

Further carrying capacity will be calculated with the formula/ relation given below-

$$r - [(P_1 - P_0) / P_1] = (r \times P_1) / K$$

Carrying Capacity will be calculated with the formula/ relation given below -

Here, K is the Carrying Capacity.

When the values for P_0 , P_1 and r are known, the value of K can be calculated out using simple rule of mathematics.

Table-4.3.3. The calculated values of Carrying Capacities (K) of three different treatments a, b and c.

K_a	K_b	K_c
21.12	19.27	15.79

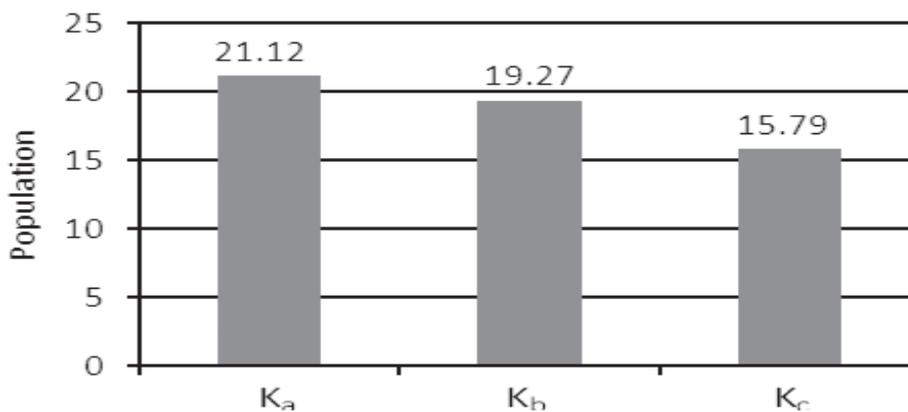


Fig.– 4.3.1. Difference of Carrying Capacity (K) under three (a, b & c) situations

Prediction of Population

Using three different K-values, future population has been predicted, using the equation below-

$$P = P + [P \cdot r(1 - p/K)]$$

$$\text{Population of the next generation} = P + [P \cdot r(1 - P/K)]$$

Where, P, the population of the previous generation. [For example, if p_t is the present generation, P_{t+1} will be the 1st generation, P_{t+2} will be the 2nd generation & similarly it will go on like P_{t+3} , P_{t+4} ]

r, the intrinsic growth rate, and K, Carrying Capacity

Note: This is possible to perform for any types of organism with respective alterations.

Table – 4.3.4. Population at every two months' intervals

Treatments	Months								
	0	2	4	6	8	10	12	14	16
A	10	16.11	22.21	20.25	21.50	20.80	21.23	20.95	21.12
B	10	14.00	15.822	19.24	19.28	19.27	19.17	19.27	19.27
C	10	12.60	13.74	15.56	15.79	15.79	15.79	15.79	15.79

When these values are put in a graph paper and points are joined, it gives a clear picture of carrying capacity as shown in figure-2.

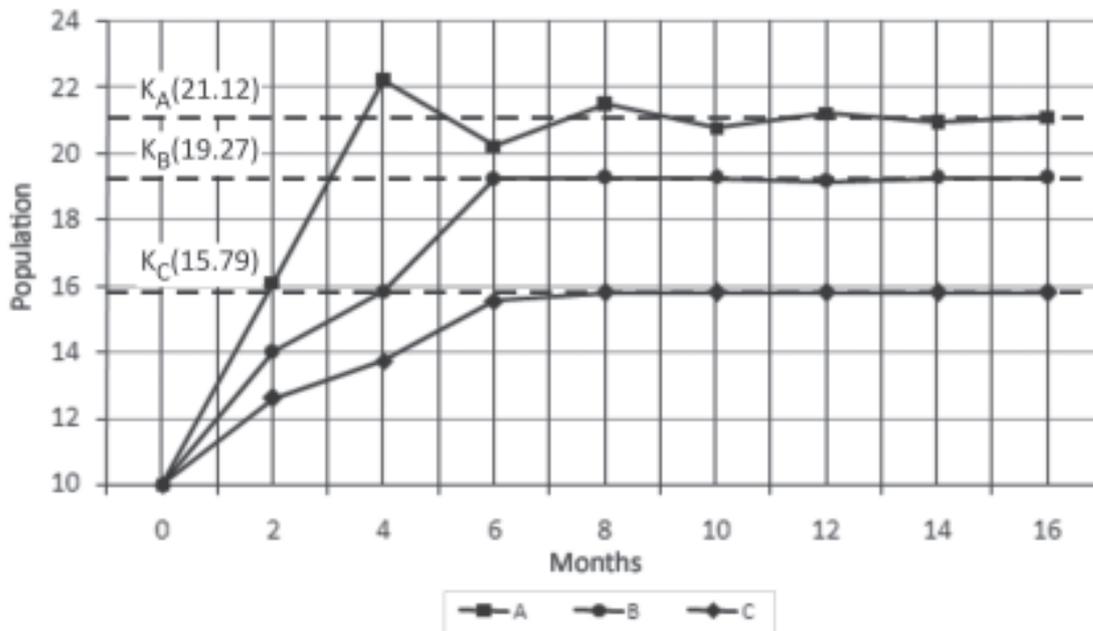


Fig-4.3.2: Predicted population with time under three different treatments. The dotted lines show the Carrying Capacities for three different situations.

Note: Explain explicitly the findings observed in the graph (Fig.-4.3.2)

Comparison of Soil Quality

For better explanation, it is essentially required to test the physic-chemical properties of the soil using simple soil testing kit available in the school. Data is to be recorded in the table (as shown in table-5). Observe the changes and try to think critically in the light of resources and environment.

Table-4.3.5. Chemical properties of soil before and after the experiment

Particulars	Initial	Final	Increase/decrease
pH			
Organic Carbon			
N			
P			
K			

Additionally, show the changes in soil quality drawing bar diagram and explain the changes and their impact on growth and survival of the organism of the study.

Inference

In all the three cases both food availability and environment were responsible for reproduction, growth and development of earthworm was responsible. This is conspicuous in the graph-2. However, the difference in the response due to amount of food availability and environmental quality with progress of time had marked influence on their reproduction, growth and overall population. Hence, hypothesis considered for the study is accepted.

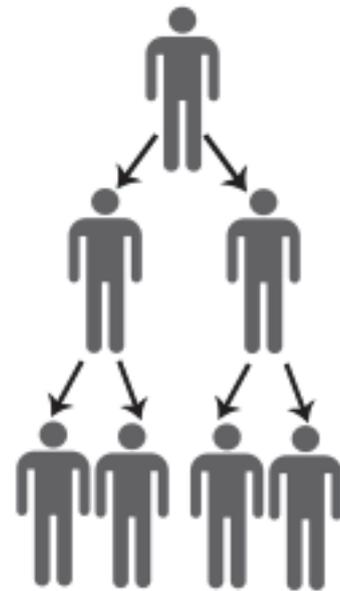
Note: Similar activities can be tried with any plants and animals.

Project-4: Infectious Disease Modeling

Throughout history, devastating epidemics of infectious diseases have wiped out large percentage of human population. To name a few are Black Death, plague epidemic, Chicken pox, flue, AIDS etc. and at present COVID-19. Although medical advances have reduced the consequences of some infectious diseases, preventing infections in the first place is preferable to treating them. Question arises, once a vaccine is developed, how should it be used? Should everyone in a society be required to be immunized and many such questions. So, understanding the dynamics of disease transmission is essential to addressing them, and mathematical model can play a role here. Once a model is formulated

that captures the main features of the progression and transmission of a particular disease, it can be used to predict the effects of different strategies for disease eradication or control.

The simplest epidemic model is the SIR model, in which members of the population progress through the three classes in order : Susceptibles remain disease-free or become infected; Infectives pass through an infection period until they are removed permanently from the grip of the disease; and a removed individual is never at risk again. Schematically the model is as –



Hypothesis

The disease is not an epidemic

Objectives

1. To find out if the disease will turn into an epidemic in the society
2. To develop model for prediction of studying nature of transmission and progression of the disease with time in the society.

Methodology

Materials

Collect data on- (i) type of the disease causing organism. (ii) population size of the area, (iii) Date of incidence of the disease, (iv) infective, recovered and death for at least 6-7 consecutive days. (iv) period of incubation of the organism

Description of SIR model

Mathematically-

$$S + I + R = N \text{ at any time (t)}$$

Where, S, susceptible; I, infective; R, Removed (recovered + deceased); N, Population; and t, time

Alike all other mathematical model, this model also consider some assumptions, as mentioned below-

- (i) No new births and migration will be taken place and/or will not be considered to avoid complication of the model.
- (ii) The population under study mixes *homogeneously*. It means, all members of the population interact (mix) with one another to the same degree.

Now, to begin formulating our model, at each time t , we divide the population N into 3 (three) classes as described above.

A disease spreads when a susceptible comes in contact with an infected individual and subsequently becomes infected. Mathematically, a reasonable number of encounters between susceptible individuals and infected individuals in an homogeneous mixing condition, is given by the product $S_t I_t$ (as per mass action principle).

However, *not all* contacts between healthy and ill individuals result infection. So, we will use a factor termed as **transmission coefficient** and it is denoted by α . It is a measure of the likelihood that a contact between a susceptible and an infected person will result in a new infection. Because the number of susceptible S_t decreases as susceptible become ill with progress of time. This, in other way may be called as interaction between an susceptible and infective. So mathematically it can be expressed by the following equation -

$$S_{t+1} = S_t - \alpha S_t I_t \dots\dots\dots (i)$$

With time, the infective class grows by the addition of the newly infected.

At the same time, some infective will either recover or die, who are not to be considered further under susceptible class and both the groups will constitute removal class.

The **removal rate**, which is denoted by $\tilde{\alpha}$, measures the fraction of the infective class that ceases to be infective further, and thus moves into the removed class at time t . Clearly, the removed class increases in size by exactly the same amount

that the infected class decreases. This leads to the additional equations, mentioned below:

$$I_{t+1} = I_t + \alpha S_t I_t - \tilde{\alpha} I_t \dots \dots \dots \text{(ii)}$$

$$R_{t+1} = R_t + \tilde{\alpha} I_t \dots \dots \dots \text{(iii)}$$

Where, S = Susceptible; I = Infective; and R = Recovered individuals; N = Population size; α =transmission coefficient; and $\tilde{\alpha}$ =removal rate; subscript t is the time span. It is usually advised to use a shorter time step.

Collectively, the three above coupled difference equations form SIR model.

How to proceed for

Before we proceed forward, there are need some basic information, like-

- What is the causal organism ((bacteria, virus, fungus, etc.)?)
- What is the contagious period of the organism? In other words, following infection, how long it takes to manifest (show) the symptoms of the disease on its host.
- What is the most target group of the organism? Is it children of certain age group? Is it male or female and if so of which age group (Ex. COVID-19 infects mostly the persons around 60 year age or above).

Steps for calculation

If we look at the three equations, the unknown parameters are the two constants α and $\tilde{\alpha}$. Value of N is known to us. So, we are to find out these two unknown values.

Step – 1. Let us consider equation (i)

$$S_{t+1} = S_t - \alpha S_t I_t$$

Or, $S_{t+1} - S_t = - \alpha S_t I_t$ [this equation is expressed as: “ $S = - \alpha S_t \tilde{\alpha} I_t$]

Or, $\alpha S_t I_t = - S_{t+1} + S_t = S_t - S_{t+1}$ (by changing the sides)

$$\text{Therefore, } \alpha = (S_t - S_{t+1}) / (S_t I_t) \dots \dots \dots \text{(iv)}$$

Once data on S_t, S_{t+1} and I_t , are available, using simple rule of mathematics, the value of α can be calculated from equation (iv).

Step – 2. During a period of time the infective class grows by the addition of the newly infected. At the same time, some infectives recover or die, and

so progress to the removed stage of the disease. The removal rate (\dot{O}) measures the fraction of the infective class that ceases to be infective, and thus move into removed class. In fact, one can estimate \dot{O} for real disease by observing infected individuals and determining the mean infection period as $1/\dot{O}$. So,

$$\dot{O} = 1/(\text{contagious period}) \dots\dots (v)$$

Step – 3. Now it is time to calculate *Basic Reproduction number* (denoted by R_0) indicates characteristics of the disease –whether it is an epidemic or not.

So, $R_0 = (\dot{a}/\dot{O})S_0$ (here, $S_0 = N$)

If $R_0 > 1$, then the disease will erupt as epidemic; if $R_0 = 1$, then a diseased

individual produces only one case and no epidemic can occur; when $R_0 < 1$, the disease dies out.

So, an epidemic occurs if and only if the Basic Reproduction Number (R_0) > 1 .

Note: The Basic Reproduction Number (R_0) plays a role in public health decisions, because a disease prevention programme will be effective in preventing outbreaks only when it ensures R_0

The Problem

Let us consider a population of 500 in a small society, being affected by some infectious disease caused by some organism, contagious/ incubation period of which is 10 days and on first day 1 person has been infected.

With the given information, we can calculate using equation (iv)-

$$\dot{a} = (500 - 499.5)/(500 \times 1) = 0.001$$

And using equation (v), $\dot{a} = 1/10 = 0.1$

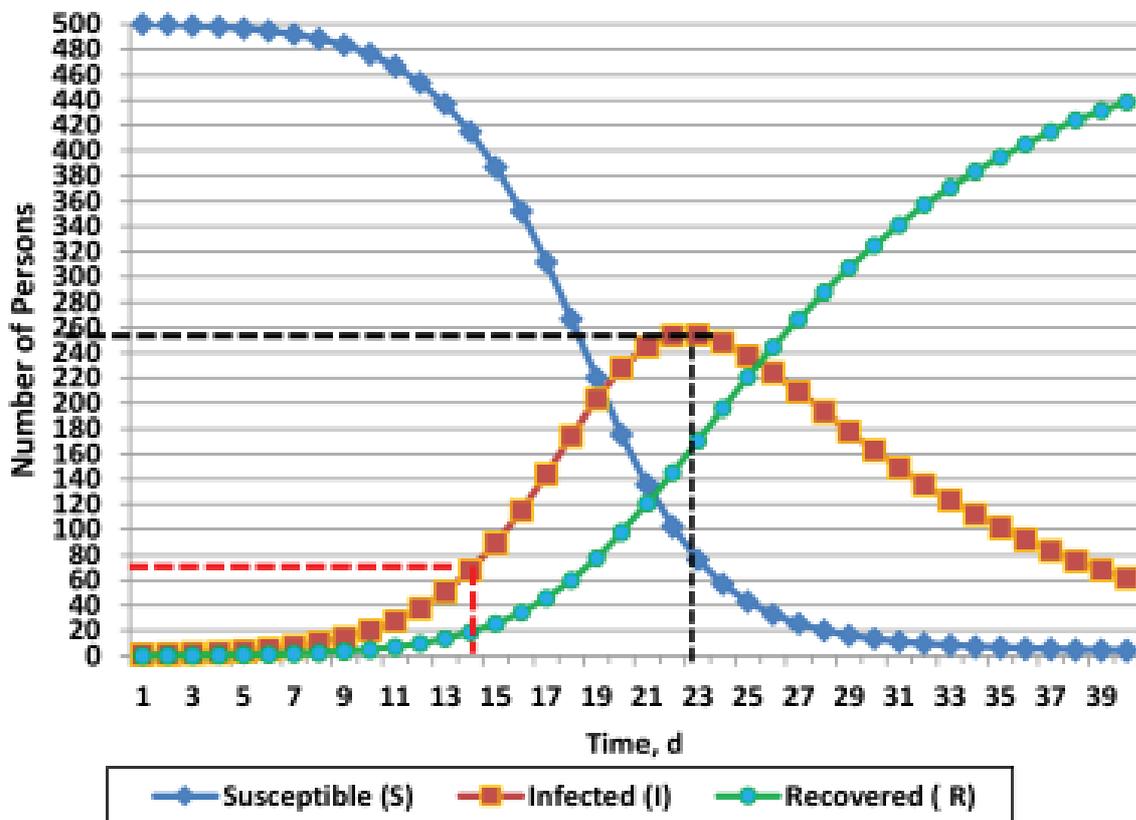
Hence, $R_0 = (0.001/0.1) \times 500 = 5$, which is greater than 1 and so the disease is an epidemic.

Once the values of \dot{a} and \dot{a} are known, using all the three equations the following data (Table – 4.4.1) for all the three classes can be calculated out and then the values need to be plotted in the graph paper keeping number of person, the dependent variable, in y-axis and time, the independent variable in the x-axis.

Table – 4.5.1. Calculated values of three different classes by day

Day	Susceptible (S)	Infected (I)	Recovered (R)	Day	Susceptible (S)	Infected (I)	Recovered (R)
1	500.00	1.00	0.00	21	135.59	244.91	120.50
2	499.50	1.40	0.10	22	102.38	253.62	144.99
3	498.80	1.96	0.24	23	76.42	254.23	170.36
4	497.82	2.74	0.44	24	56.99	248.23	195.78
5	496.46	3.83	0.71	25	42.84	237.55	220.60
6	494.56	5.35	1.09	26	32.67	223.98	244.36
7	491.91	7.46	1.63	27	25.35	208.90	266.76
8	488.24	10.38	2.37	28	20.05	193.30	287.65
9	483.17	14.42	3.41	29	16.18	177.85	306.98
10	476.21	19.94	4.85	30	13.30	162.94	324.76
11	466.71	27.44	6.85	31	11.13	148.81	341.05
12	453.90	37.50	9.59	32	9.48	135.59	357.35
13	436.88	50.78	13.34	33	8.19	123.31	370.91
14	414.70	67.88	18.42	34	7.18	111.99	383.24
15	386.54	89.25	25.21	35	6.38	101.60	394.44
16	352.05	114.82	34.13	36	5.73	92.09	404.60
17	311.63	143.76	45.62	37	5.20	83.40	414.76
18	266.83	174.18	59.99	38	4.77	75.50	423.97
19	220.35	203.24	77.41	39	4.41	68.31	431.52
20	175.57	227.70	97.73	40	4.11	61.78	438.35

Fig-4.4.1. Indicates the nature of dynamics of the disease among three classes



Conclusion

1. It appears from the figure- 4.4.1, that the infection will be peak by 23rd day from the day of first informed case while around 250 persons or 50% of the population of the area will be infected (shown by black dotted line). So the intervention is essential to bring down the curve towards flattening adopting appropriate measures to prevent the spread the epidemic.

2. But it is better to take the appropriate actions towards prevention at the time as soon as it reaches the inflection point on 12th day affecting 40 numbers i.e. 8% of the population (shown by red dotted line)

ATTENTION

1. This model can also be solved by differentiation as well as exponentially.
2. The SIR model is applicable for diseases in the animals other than human being.. Such as Foot and Mouth disease in cow, Ranikhet disease in poultry and also diseases in fishes.
3. In case of large data, analysis can be done by taking proportionate values with respect to the total population.

Additional Project Ideas

(A) Design

1. Design different methods to purify water by using natural materials around you and compare them.
2. Study different systems of water transportation and design an improved product to transport water from source to home.
3. Design an improved product for reducing the burden of headloads of labour workers.
4. Design your own structure for an earthquake-proof house.
5. Design a house for flood prone area based on the challenges faced.
6. Study the design of the tradition housing in your region in relation to the climatic conditions
7. Design a utility-based product from natural waste available in your surroundings. Explore the scientific principles involved in making and application of that product.
8. Find golden ratio in different products around you and explain the science behind using the golden ratio.

9. Find an interesting element in nature around you like leaf, spider web, bird nest, flowers, etc., understand its scientific principle and possibility and design a product being inspired from it.
10. Identify a specific problem or need in your community. Design a product based on participatory design principle addressing that need.
11. Model the energy consumption in your locality and make a comparison based on different housing designs and systems.

(B) Planning:

1. Study the Supply Chain of Dabbawala in a city or town supplying home-cooked food. Understand their challenges, propose solution.
2. Map the vulnerability of your school in the context of flood or earthquake.
3. Prepare an evacuation plan for your school in case of a fire incident.
4. Develop ideas for increasing the system efficiency in biomass.
5. Understand the current scenario of Solid Waste Management system in your locality and propose viable better ideas.
6. Map the planning involved for public transport system in your area in relation to the need. Suggest possible ideas for improvement of the system.

(C) Modeling:

1. Study on climatic factors of your locality
2. Establish mathematical relation between Body Mass Index (BMI) and Basal Metabolic Rate (BMR)
3. Map the relationship between rainfall and stream flow
4. Comparative study on different plant species using Golden Ratio
5. Map nearby facilities like hospitals, offices, places of interest in 3 km radius of your locality
6. Map ground water level in your village by studying the wells in the area
7. Map the drainage lines in your area and categorise them in natural and man-made understanding its benefits and lacking.
8. Map the changes on the coast line of a specific region of India compared to the natural disasters faced in the region.
9. Map the green cover in your region compared to the land availability and usage.
10. Study on agriculture land use of a village using map as a tool and assess the agricultural self-sufficiency and food security.
11. Model the changes observed in habitats of animals in your surroundings.