Design Research Seminar

Biomimicry in design: Approach towards smart farming technology

Samyak Khobragade
176390011 (2017-19)

Mobility and vehicle design
IDC, IIT Bombay.

Guide- Prof. Nishant Sharma

IDC
IIT Bombay

DECLARATION

I declare that this written report represents my own idea in my own words, and where others, ideas or words have been included, I have mentioned the original source. I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea, data, facts or source in my submission.

I understood that any violation of the above will be cause for disciplinary action by the institute and can also penal action from the source from which proper permission has not been taken, or improperly cited.

Signature -

Name - Samyak Khobragade

Roll No - 176390011

Date -

Approval sheet

This is Design research seminar project entitled “Biomimicry in design: Approach towards smart farming technology”, by Samyak Khobragade is approved in partial fulfilment of the requirement for Master of design in Mobility and Vehicle Design.

Project Guide:

Prof. Nishant Sharma

Table of contents

		Page no.
1. Introduction		1
2. Farming in nature		4
	2.1 Damselfish	4
	2.2 Yeti crab	5
	2.3 Leaf cutter ants	5
	2.4 Ambrosia bettle	5
	2.5 Termites	6
	2.6 Spotted jellyfish	6
	2.7 Bowerbird	6
3. Trends in agriculture		7
	3.1 Vertical farming	7
	3.2 Organic farming	7
	3.3 Precision farming	8
4. Robots in Farming		8
	4.1 Bonirob	8
	4.2 eBee Ag	8
	4.3 Grizzly RUV	9
	4.4 Autonomus tractor	9
	4.5 Small robot company	10
5. Scenario		11
6. Conclusion		14
7. References		15

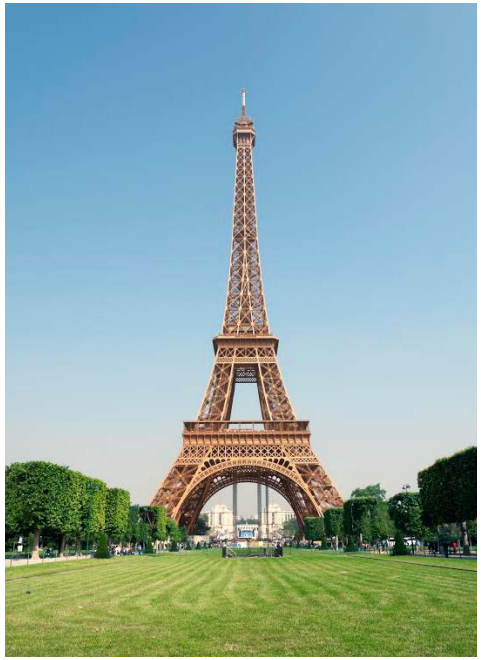
1. Introduction

In ancient Greek bios means life and mimesis means imitation. Biomimetics or biomimicry is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems.[1] Biomimicry is not a new concept in fact traces of the notion can be found in the past, for example the rib structure of Eiffel tower(1884) was inspired from the human femur (thigh bone) and the Eddystone light house (1759) located in southern England was modelled based on the shape of the oak tree, the structure remained intact for almost a century before it required repairs.

John George Wood was an English priest in nineteenth century, he devoted his life to write about natural history. In 1885 he published Nature's teachings - Human Invention Anticipated by Nature, in which he drew upon his lifetime of observations to produce a remarkable account of hundreds oh human inventions and how they were linked to biological mechanisms. "It is, that as existing human inventions have been anticipated by Nature, so it will surely be found that in Nature lie the prototypes of inventions not yet revealed to man. The great discoverers of the future will, therefore, be those who will look to Nature for Art, Science or Mechanics, instead of taking pride in some new invention, and then find that it existed in Nature for countless centuries" (J.G.Wood, 1885) The applications of biomimicry can be divided into four major areas i.e. shape, surface, structure and production.[6]

There are also other fields like Artificial intelligence, swarm intelligence etc. where scientists are using biomimicry as a tool. In 2030 the food demand of the world is going to increase by 20 percent and current practices in agriculture are social and environmental disaster. [2] To overcome this problem a change on system level is required and these changes will radically transform our agricultural system. Humans are not only organisms who grow their own food in fact there are many creatures who have been farming since millions of years. Other organisms do farming in a sustainable way unlike humans; for example leaf cutter ants grow fungus which is the main source of food and Damselfish is know for growing algae gardens.[3] Currently a number of organizations are working in the

Img 1- Human femur



Img 2- The Eiffel tower

Img 3- Oak trunk

Img 4- Eddystone light house

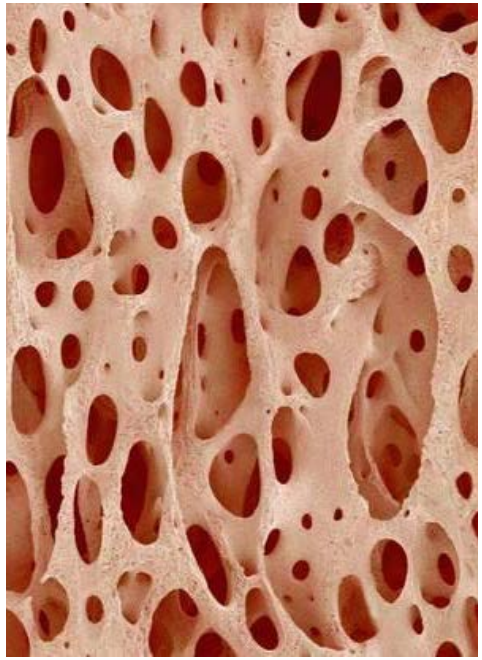
field of sustainable farming and techniques like organic farming, vertical farming etc. are becoming popular all over the world. People are also working in the field of autonomous and precision farming where they are using a variety of machines like drones, automated tractors etc. to farm without any human intervening the field. But there are major concerns related to this new vision of agriculture where next generation biotechnologies will re-engineer plants and animals, use of water and pesticides will be optimised by precision farming and Global food systems will rely on smart robots, block-chain and the internet of things to manufacture synthetic foods for personalised nutrition.[4] This new approach of farming is designed for agricultural giants not for small farmers and hence these new innovations will reinforce the political and economical power in the hands of a few corporations. Not only this but expansion of this technosphere will have adverse effect on the biosphere; small flying robots will be used to pollinate flowers instead of bees and robots will do all the farming operations instead of farmers. There can be another approach to smart farming and this paper explores other possibilities where concepts of biomimicry, sustainable farming, robotics and internet of things can be used to find a viable solution. Finally the paper presents a scenario of smart farming with the help of a story board.

Img 5- Kingfisher bird

Img 6- Shinkansen 500

Img 7- Burdock seedpod

Img 8- Velcro tape



Img 9- Bone tissue structure

Img 10- 3D printed chair

Img 13- Fire ants

Img 14- Self assembly system

Img 11- Fermented tea

Img 12- Grown garments

2 Farming in nature

Humans started farming about 10000 years ago and it changed everything for us; humans started domesticating plants and animals and storing food due to the surplus supply. Humans gave up the nomadic culture and adapted permanent settlements. In Eurasia, the Sumerians started to live in villages from about 8,000 BC, relying on the Tigris and Euphrates rivers and a canal system for irrigation. Ploughs appear in pictographs around 3,000 BC; seed-ploughs around 2,300 BC. Farmers grew wheat, barley, vegetables such as lentils and onions, and fruits including dates, grapes, and figs. From the twentieth century, intensive agriculture increased productivity. In recent years there has been a backlash against the environmental effects of conventional agriculture, resulting in the organic, regenerative, and sustainable agriculture movements. But if we look closely humans are not the only organisms who grow their own food, some species of ants and beetles have been growing fungus since past 50 million years.[7]

Img 15- Record of early farming practices

Img 16- Ancient paddy fields in China

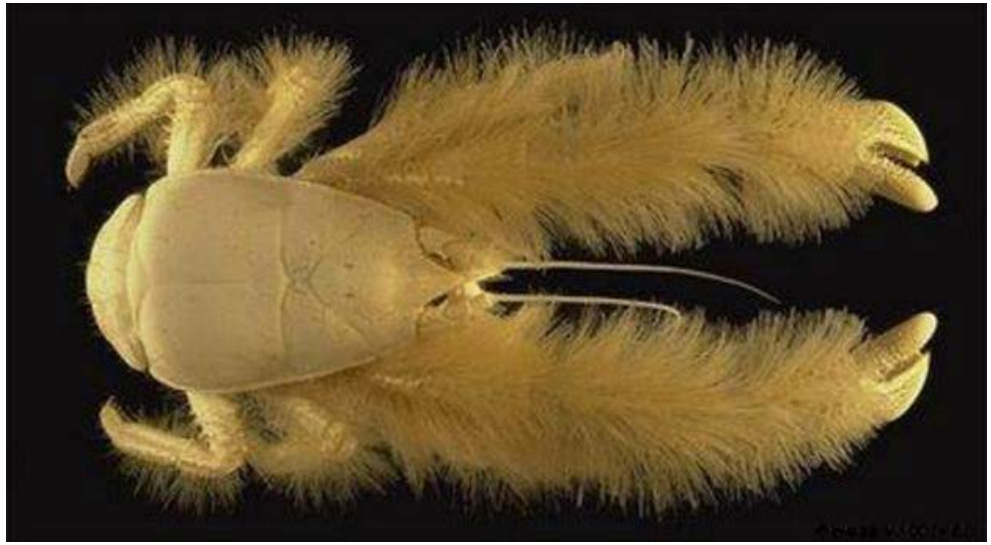
2.1 Damselfish

Damselfish are one of the most abundant fish on coral reefs across the world, from the Caribbean to Indonesia. Some species forage on tiny crustaceans but many stake out permanent gardens among the coral to cultivate algae. They also protect their algal gardens from would-be thieves.[3]

Img 17- Damselfish in algae garden.

2.2 Yeti crab

The Yeti crab uses its bristly claws to raise bacteria, which capture energy from the gases released by the seeps, before grazing on them with its comb-like mouthparts. The yeti crab waves its claws back and forth to stimulate bacterial growth. With every swing of their arms, the crabs churn up water and seepage to ensure that the bacteria get fresh supplies of oxygen and hydrogen sulphide.



Img 18- The Yeti Crab

2.3 Leaf cutter ants

The leaf cutter ants collect leaves to use as manure for their complex underground fungi farms, leaf cutter ants have been growing their own food for up to 50 million years. Specialized workers called mediae forage around for plant material — they have been known to strip a citrus tree clean in a single day — which they lug back to the nest. Then minims chew them up, compost them and feed the leaves to the fungi in one of the most elaborate forms of insect agriculture ever documented. These common social insects live in huge underground colonies (large groups of related ants) of up to many millions of ants.

Ants, like all insects, have jointed legs, three body parts (, a pair of antennae, and a hard exoskeleton. The exoskeleton is made up of a material that is very similar to our fingernails.[13]

Img 19- Leaf cutter ants

2.4 Ambrosia beetles

The ambrosia beetle carves tunnels into decaying tree trunks, carries fungi in special receptacles on its body and deposits the spores into hand-built chambers. The fungi then grows by drawing nutrients from the wood. The beetles carefully tend to their crops. Once their larvae are fully grown, they fly off to bore into new trees and restart the process.[5]

Img 20- Ambrosia beetle cultivating fungus.

2.5 Termites

Termites are famous for having one of the most complex social systems in the animal kingdom. Their nests are amazingly precise fungus growing farms. Termites create chambers which have the perfect amount of heat and airflow required to grow fungus, which is their primary food source. [5]

2.6 Spotted jellyfish

The spotted jellyfish is an expert algae farmer, and the creature uses its own body tissues as the growth chamber. During the daylight hours, spotted jellyfish spend the vast majority of their time orientating themselves to catch the most amount of sunlight. The photosynthetic crop flourishes inside their internal gardens, giving the jellyfish an unlimited supply of fresh algae to consume.[5] Their native distribution is around Cairns, Queensland, Australia, and Thailand. Having its native habitat extend north from eastern Australia up to South East Asia.

Img 22- Spotted jellyfish

2.7 Bowerbird

Bowerbirds and their potato bushes are the first known example of the cultivation of a nonfood plant by a nonhuman species. They construct elaborate nests, also known as bowers, from twigs which they then decorate with various objects to attract the females. As males don't tend to build their nests in areas where the berries grow, they throw the dishevelled berries outside the nest. By the time the bower is a year old, they usually have a few dozen bushes growing nearby, giving them more opportunity to attract the female.[5]

Img 23- Bower bird

3 Trends in agriculture

The Agriculture industry is changing dynamically and new trends are emerging to fulfil the increasing demand of food all around the world. Some trends like organic farming focus the quality of food while autonomous or vertical farming focus on increasing the yield with maximum efficiency.

3.1 Vertical farming

A vertical farm grows plants and produce by stacking the plants. This is accomplished by using growing shelves suspended on a wall or fence, which uses much less space than growing the plants on the ground. Thereby, maximizing the available space. Letcetra Agritech founded by Ajay Naik is a goa based company which specializes in vertical farming.[9]

Img 24- Ajay Naik in his vertical farm

Img 25- Ajay Naik in his vertical farm

3.2 Organic farming

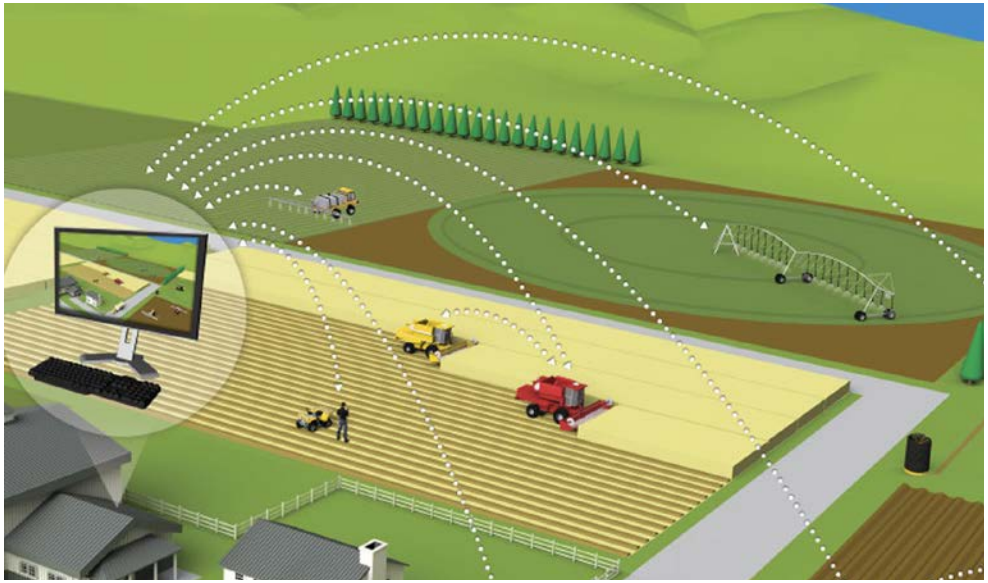
Organic farming system in India is not new and is being followed from ancient time. It is a method of farming system which primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes.[10]

Img 26- Organic farm in India

3.3 Precision farming

Precision agriculture is a farming management concept based on observing, measuring and responding to intra-field variability in crops. The goal of precision agriculture research is to define a decision support system for whole farm with the goal of optimizing returns on inputs while preserving resources.[11] In Precision farming all critical decisions taken on the field by farmers is based on data and technology that interprets the data for them to make a value judgement. Some enterprising farmers have even gone to the extent of deploying Blockchain technology to interpret the volumes of data they have generated from their fields kick-starting what is come to be called 'digital farming'.[12]

Img 27- Case autonomous tractor



Img 28- Diagram representing precision farming

4 Robots in agriculture

Researchers in the United Kingdom have successfully grown the world's first crop of barley using nothing but robot tractors and drones. The goal was to grow a cereal crop using autonomous machinery and remote agronomy. From establishment to harvest, no humans shall enter the field. It is called the hands free hectare.

Img 29- Hands free hectare

4.1 Bonirob

Bonirob can work in team to remove weeds from the land and applying fertilizer. The robot is autonomous, and designed to work in tandem with other models.[14]

Img 30- Bonirob

4.2 eBee Ag

eBee Ag is a drone that surveys the land from above, taking high-resolution shots to help farmers plan spraying and planting. It can also create 3D images and overlays.[14]

Img 31- ebee Ag

4.3 Grizzly RUV

Grizzly RUV from Clearpath Robotics is a big robot for big jobs like hay baling. It also has laser sensors precise enough that it knows where grass might need to be treated.[14]

Img 31- Grizzly RUV

4.4 Autonomous tractor

Autonomous tractor, GPS-guided equipment that carries sensors to avoid obstacles. The Autonomous Harvest System is a collaboration between Kinze Manufacturing in Williamsburg, Iowa, and Jaybridge Robotics.[14]

Img 32- Autonomus tractor

4.5 Small Robot Company

Small Robot Company is an agri-tech start up commercialising a deceptively simple idea: replacing much of the work done by tractors in fields with a series of highly accurate, smart, lightweight robots. They have developed three autonomous robots for farming. 90% less energy is needed when combination of robots with AI-driven precision farming is used. This means more than 95% less fertiliser and pesticide is used. It also increases yields. Reducing compaction improves soil health and root growth, meaning healthier plants. Also the crop is spaced perfectly. There is greater germination across more of the field from less seed. And less disease and nutrient deficiency. Switching to robots is a technological leap forward.Robots are smaller, lighter and more agile than tractors. They don't need to plough. They just push each seed into the ground when it's ready. [15]

Img 33- Small robot company founders

Tom robot stays on the farm and digitises your fields. He monitors each and every plant, keeping track of the health and development of the farm.[15]

Img 34- Tom robot

Dick robot is comparatively bigger in size at stays in Small Robot Central, but is brought out to the farm when he is needed. Dick micro-sprays each plant with fertilisers or chemicals as required to help it thrive. [15]

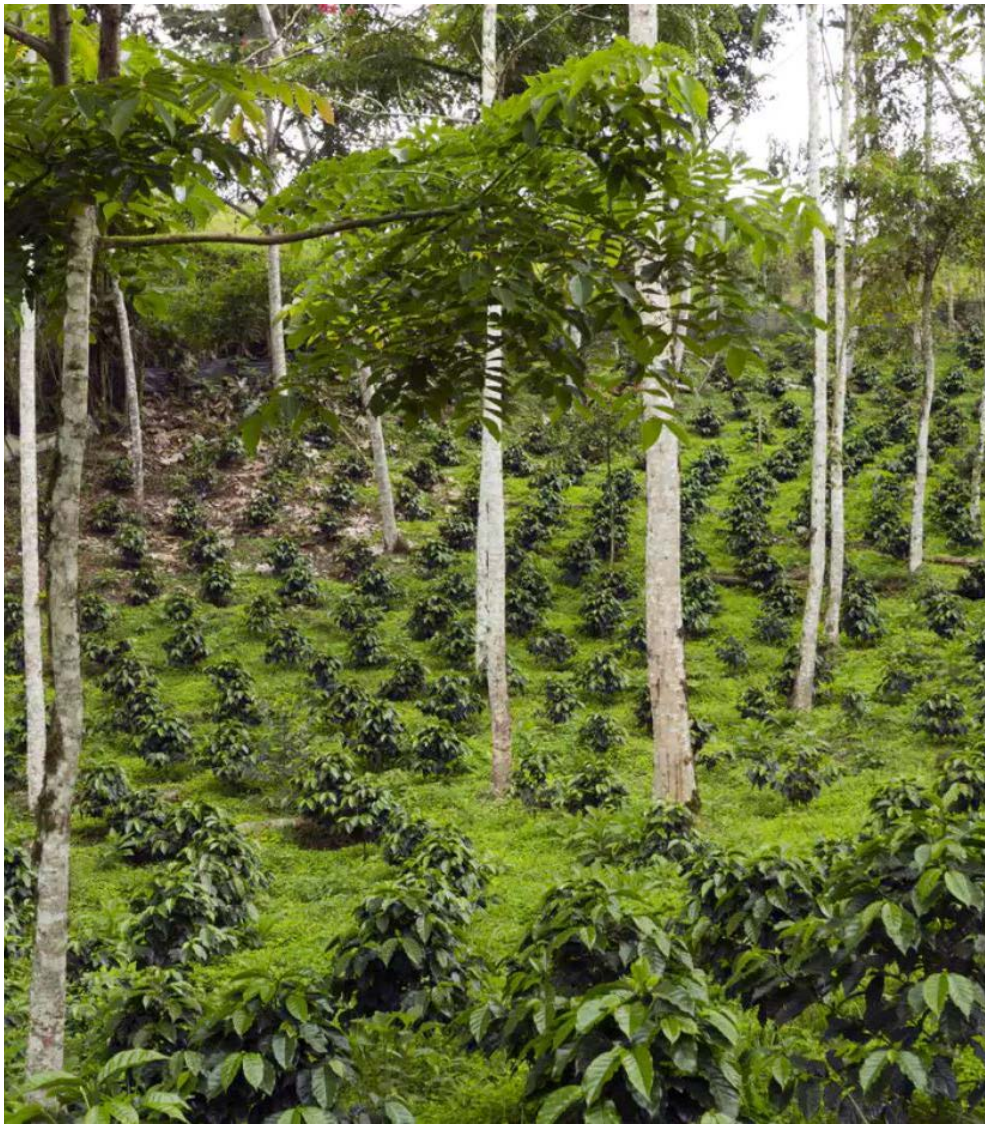
Img 35- Dick robot

Harry is the world's first robotic drill for combinable crops. It places individual seeds in the ground and accurately records exactly where he has placed them.[15]

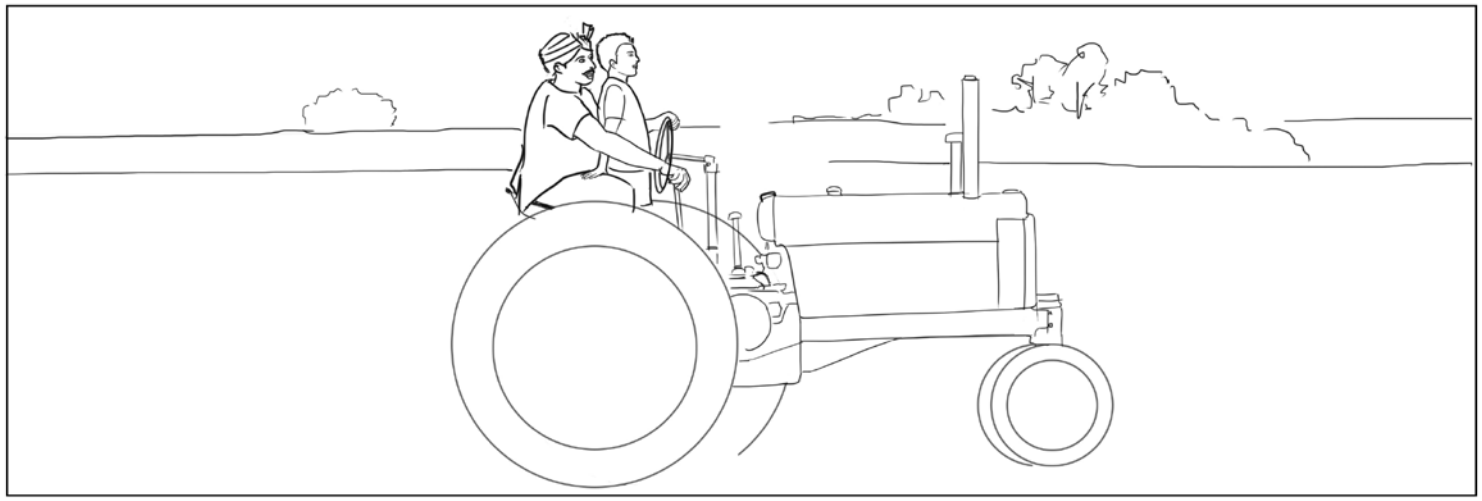
Img 36- Harry robot

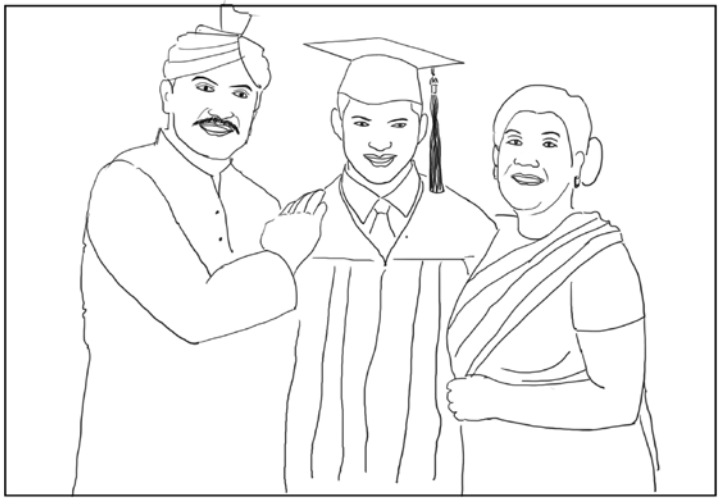
5 Scenario

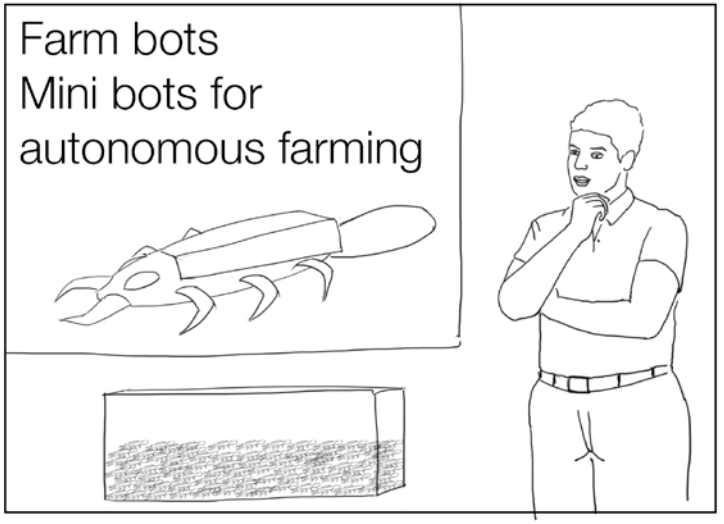
It is 2019, Rohan is a twelve year old who lives in Nasik with his family of four; his father, mother and little sister. His father is a farmer and owns 10 hectare of land, they have a comfortable life. Rohan is brilliant at studies and dreams to become an engineer none the less he also helps his father in farming activities and enjoys being close to the nature.
Ten years later he graduates from IIT Bombay and starts working with an engineering firm in Navi Mumbai. His sister is studying in Mumbai and stays with him. Due to his fathers poor health his parents also move permanently to Mumbai with their children. Rohan doesn't want to sell his ancestral land because he has an emotional connection with it and wants to grow some plants on his land due to his love for the land.
One day Rohit goes to a agricultural exhibition and finds a unique set of small robots. These robots are autonomous and they are capable of taking care of a piece of land without any human help. The robots work on the principle of Agroecology which is the study of ecological processes applied to agricultural production systems. Bringing ecological principles to bear in agroecosystems can suggest novel management approaches that would not otherwise be considered.[16]These small winged robots are solar powered and rely on appropriate biodiversity to take care of the plants rather depending on fertilizers or insecticides. In contrast to others these robots work in circular systems that involve recycling, reuse and combining resources to reduce dependency on external inputs, in particular fossil fuels. They mimic natural cycles and the functional diversity of natural ecosystems. These robots are inspired by ants and they can assemble to create different forms like the fire ants to complete the required job; like the leaf cutter ants they can cut leaves and make organic manure for the plants. Moreover these little bots work in groups like the ants and different groups can perform various activities at any given time. The activities include planting individual seeds in natural way, keeping a surveillance on the plants and animals on the land, watering the plants if required, creating and feeding fertilizers to the plants, keeping the track of weather, taking action against any pests or diseases if required and collecting the yield. Rohan has access to this information all the time and after the yield is obtained he decides what to do with it, He can send the yield to himself in Mumbai and sell the surplus to local buyers or online. With the help of these bots Rohan can take care of his job as an engineer and also his ancestral land; while doing so he is not harming nature and also gaining decent yield and income from the land.

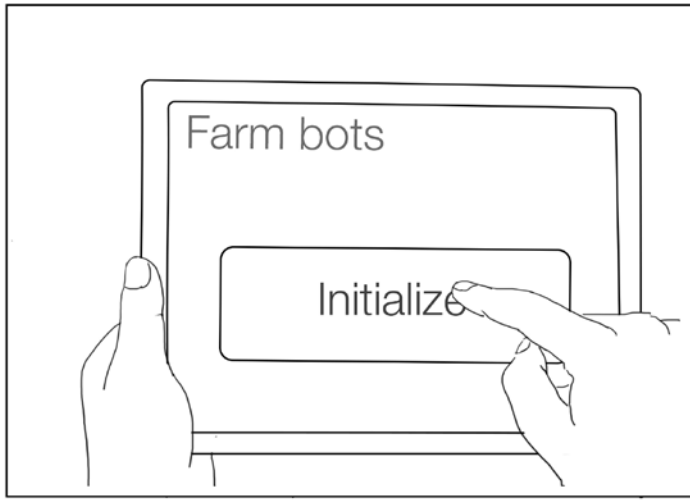


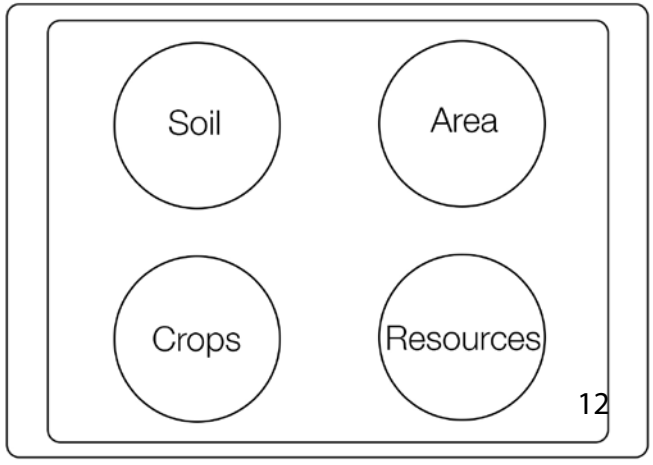
Img 37- Multiple crop system



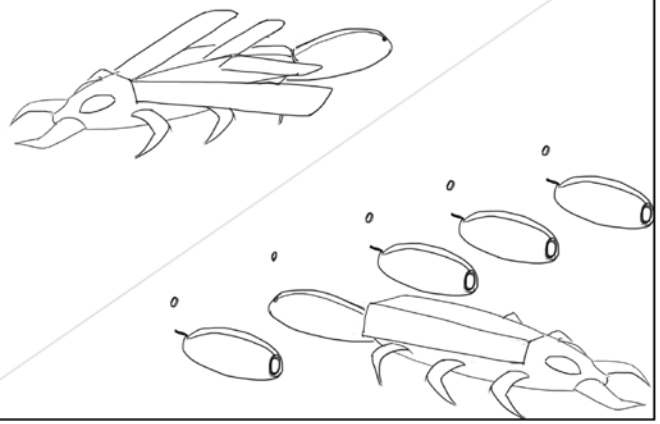



Farm bots
Mini bots for
autonomous farming

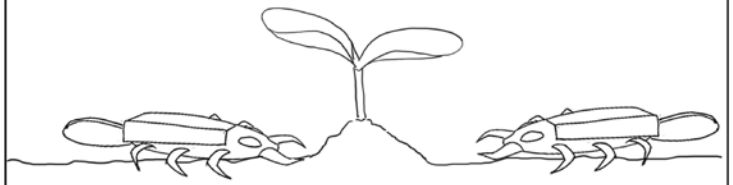

Farm bots
Initialize


Soil
Area
Crops
Resources

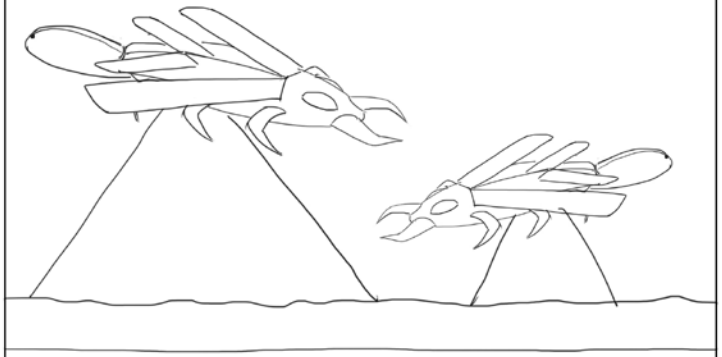
Solar wings and replaceble battery



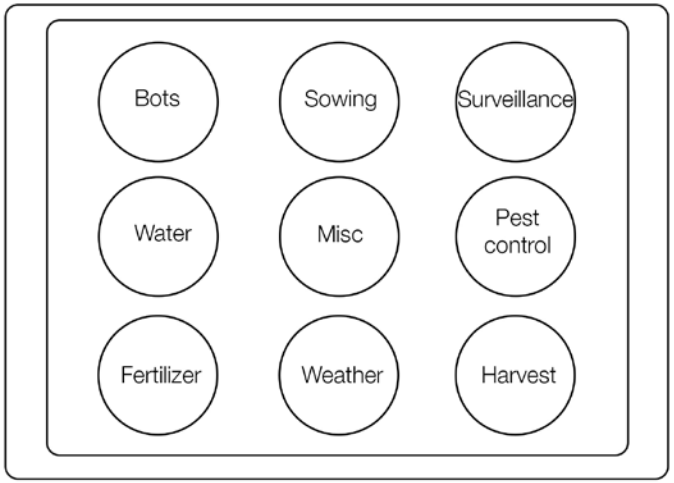
Bot taking care of sapling



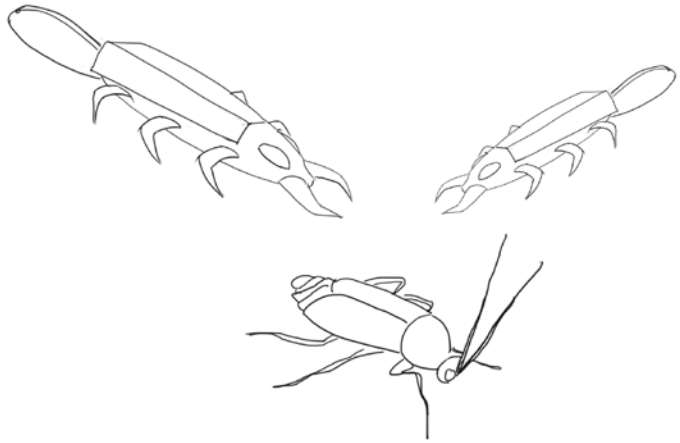
Surveillance while flying



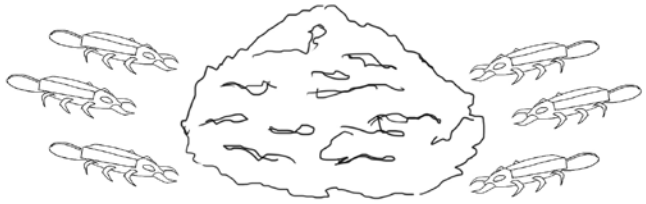
Bot collecting dew



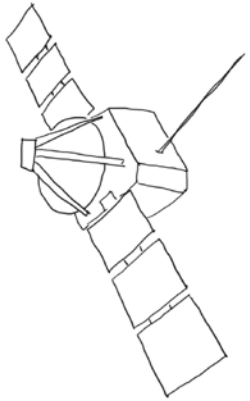
Pest control



Creating organic fertilizer



GPS Weather tracking



Yield delivered to Rohan

6 Conclusion

To conclude by combining the concepts of biomimicry, agroecology and technology sustainable agroecosystems can be created and managed. These kind of systems can contribute the quality of food and also help in democratisation of food systems. Pollution and soil erosion is minimised to create a sustainable system. The scenario presents a future where agroechological innovations insure that we can feed ourselves and our networks in a reasonable, environmentally regenerative, and socially rich way rather living in a world in which mass produced food is delivered by automated robots and organizations that put benefits previously individuals.

References

[1] https://en.wikipedia.org/wiki/Biomimetics
[2] http://www.fao.org/english/newsroom/news/2002/7833-en.html
[3] http://www.bbc.com/earth/story/20150105-animals-that-grow-their-own-food
[4] https://theconversation.com/the-battle-for-the-future-of-farming-what-you-need-to-know-106805
[5] https://www.care2.com/causes/8-animals-that-know-how-to-farm-their-own-food.html
[6] Biomimietics for designers - Veronica Kapsali
[7] https://en.wikipedia.org/wiki/History_of_agriculture
[8] https://www.agweb.com/article/five-trends-shaping-the-future-of-farming/
[9] https://www.thebetterindia.com/79003/ajay-naik-goa-hydroponic-farm-software-engineer/
[10] http://agritech.tnau.ac.in/org_farm/orgfarm_introduction.html
[11] https://en.wikipedia.org/wiki/Precision_agriculture
[12] https://www.thehindubusinessline.com/opinion/precision-farming-is-a-game-changer/article25324585.ece
[13] https://www.enchantedlearning.com/subjects/insects/ant/leafcutter.shtml
[14] https://www.popularmechanics.com/technology/robots/g1867/5-farm-robots-ag-industry/?slide=3
[15] https://www.smallrobotcompany.com/meet-the-robots/
[16] https://en.wikipedia.org/wiki/Agroecology

Image sources

Image 1 (http://www.thestudymcr.com/collections/human-remains/femur/)
Image 2 (https://www.aesu.com/wp-content/uploads/2014/05/Eiffel-tower.jpg)
Image 3 (https://www.artstation.com/artwork/oDVlL)
Image 4 (https://nl.wikipedia.org/wiki/Eddystone_Lighthouse)
Image 6 (https://in.pinterest.com/pin/20758848253354271/?lp=true)
Image 5 (https://www.dailymail.co.uk/news/article-4609128/Amateur-photographer-captures-kingfisher.html)
Image 7 (https://www.frozenseeds.com/products/lesser-burdock-seeds-arctium-minus)
Image 8 (https://www.today.com/money/velcro-creates-song-get-people-stop-using-name-velcro-wrongly-t116707)
Image 9 (https://www.allposters.com/-sp/Bone-tissue-of-a-hen-magnified-x25-Posters_i8657015_.htm)
Image 10 (https://www.youtube.com/watch?v=QyX6ZGuFgkc)
Image 11 (https://en.wikipedia.org/wiki/Kombucha)
Image 12 (https://theamccarthy.wordpress.com/2012/11/27/grow-your-own-jacket-biocouture/)
image 13 (https://www.latimes.com/science/sciencenow/la-sci-sn-fire-ants-liquid-solid-self-healing-bioinspired-20131126-story.html)
image 14 (https://betanews.com/2014/08/18/harvard-scientists-develop-a-self-organizing-thousand-robot-swarm/)
image 15 (https://en.wikipedia.org/wiki/History_of_agriculture)
image 16 (https://en.wikipedia.org/wiki/History_of_agriculture)
image 17-23 (http://www.bbc.com/earth/story/20150105-animals-that-grow-their-own-food)
image 24 (https://www.thebetterindia.com/79003/ajay-naik-goa-hydroponic-farm-software-engineer/)
image 25 (http://agritech.tnau.ac.in/org_farm/orgfarm_introduction.html)
Image 26 (https://en.wikipedia.org/wiki/Precision_agriculture)
image 27 (http://www.vantage-ro.com/en/news/5-precision-agriculture-technologies-searched-by-farmers/)
image 28 (http://www.vantage-ro.com/en/news/5-precision-agriculture-technologies-searched-by-farmers/)
image 29-32 (https://www.popularmechanics.com/technology/robots/g1867/5-farm-robots-ag-industry/?slide=3)
Image 33-36 (https://www.smallrobotcompany.com/meet-the-robots/)
Image 37 (https://theconversation.com/the-battle-for-the-future-of-farming-what-you-need-to-know-106805)