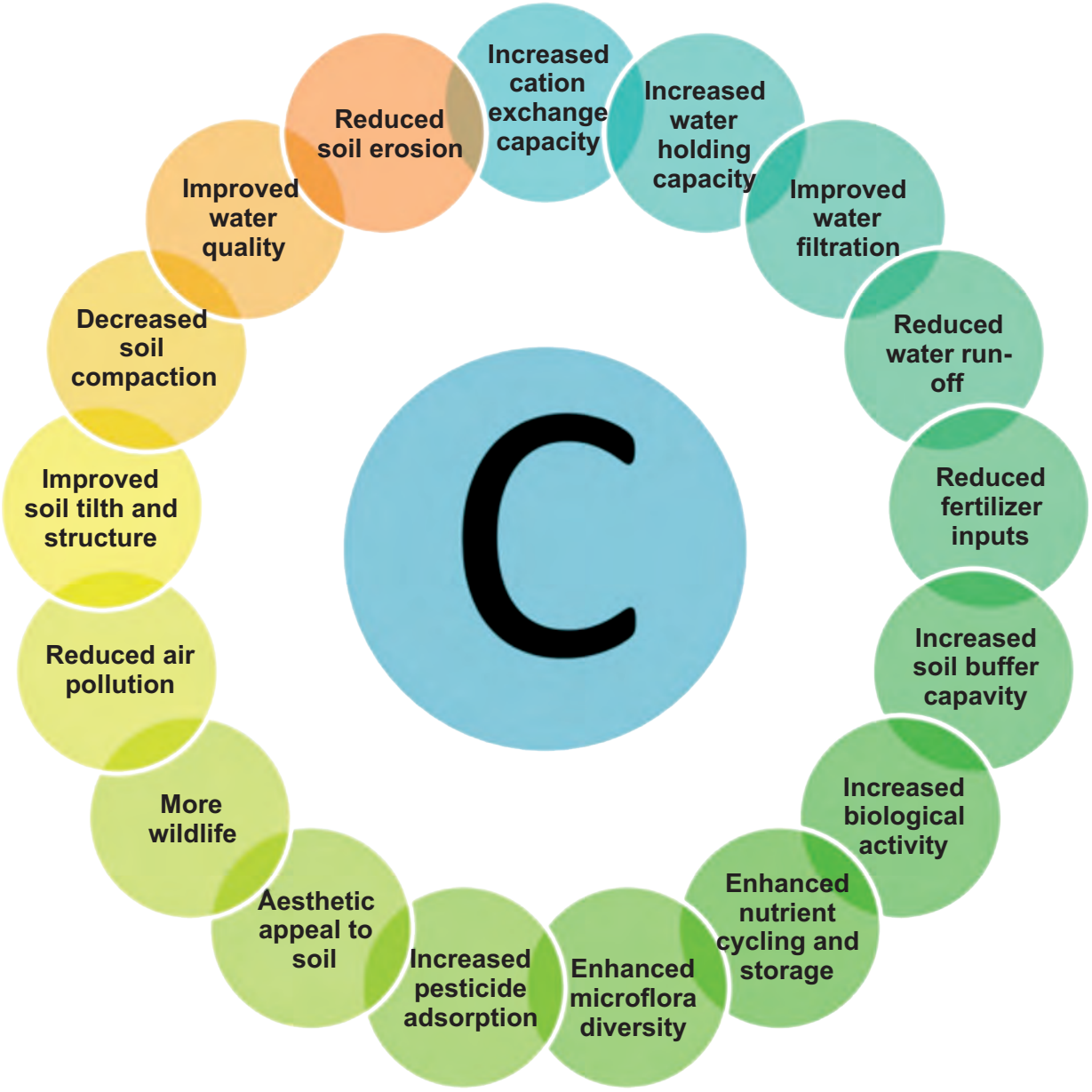
Navdanya

# SEEDS OF HOPE, SEEDS OF RESILIENCE




## How Biodiversity and Agroecology offer Solutions to Climate Change by Growing LIVING CARBON


Dr Vandana Shiva

With Dr Vinod Bhatt, Dr Ashok Panigrahi, Kusum Mishra, Dr Tarafdar, Dr Vir Singh

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# 1

# Climate Change and Biodiversity Erosion: Common Roots of Interconnected Crises in Fossil Fuel based Industrial Agriculture

Today, we are faced with two life threatening planetary crises – climate change and species extinction. Both crises are inter-connected, and have common roots. Our current modes of production and consumption based on fossil fuels - starting with the industrial revolution and intensified by the advent of industrial agriculture, have contributed to both these crises.

**The last two centuries of dependence on fossil fuels has created multiple distortions in our view of the world, of our production and consumption systems, of our ideas of efficiency and productivity, of our ideas of technological progress, of the way we produce and distribute our food.**

We use more resources to produce the goods we consume, and call it more "productive". We create more waste and more externalities that the earth and others have to bear, and we call it more "efficient". We degrade the planet, push species to extinction at 1000 times the normal rate, we are making the planet unliveable because of climate chaos, and we call it progress.

The emissions from fossil fuel based economic activities are termed, by the scientists who have been studying climate change, as anthropogenic emissions - originating from human activity. The Intergovernmental Panel on Climate Change (IPCC) has recognized that since 1750 the net effect of human activities on the earth's climate has been one of warning. Certainly about the anthropogenic basis for climate change has gone from greater than 66 percent to greater than 90 percent.

If no action is taken to reduce greenhouse gases, we could experience a catastrophic 4°C increase in temperatures by the end of the century.

Climate change is not just about global warming and rising temperatures. The desatabilisation of the climate system is leading to the intensification of droughts, floods, cyclones and other extreme weather events. Year after year the frequency and intensity of these extreme events is increasing. Climate Change is already a life and death issue in large parts of the world.

In 1992, at the Earth Summit, the International community adopted two major ecological principles – the precautionary principle and the polluter pays principle, and signed two legally binding agreements – The UN Convention on the Conservation of Biodiversity,(CBD) and UN Framework Convention on Climate Change (UNFCC).

Both treaties were shaped by the emerging ecological sciences and the deepening ecology movement. one was a scientific response to the ecological impact of pollution of the atmosphere due to use of fossil fuels. The second was a scientific response to the genetic pollution caused by GMOs and the erosion of biodiversity due to the spread of industrial, chemical monocultures. Three years after Rio, the UN Leipzig Conference on Plant Genetic Resources assessed that 75% biodiversity had disappeared because of the Green Revolution and Industrial farming. The FAO estimates, 70-90% of global deforestation is due to Industrial Agriculture pushing it's monocultures further and further into forests to grow commodities for export - not for food. Disappearance of pollinators and beneficial soil organisms are other dimensions of biodiversity erosion due to industrial agriculture.

Most of mankind now lives on no more than 12 plant species, with the four biggest staple crops (wheat, rice, maize and potato) taking the lion's share

(Esquinas Alcazar 2010). In India, rice varieties have declined from an estimated 200,000 before colonialism, to 30,000 in the mid 19th century with several thousand more varieties lost since the imposition of Green Revolution on India, in the 1960s. Similarly, Greece is estimated to have lost 95% of its traditional wheat varieties after being encouraged to replace local seeds with 'modern' varieties developed by CIMMYT. The disappearance of this diversity in our diets has manifested in the epidemic of malnutrition, especially amongst the world's poor. Having created the epidemic, this failed system of chemical agriculture would like to force 'Golden Rice' and 'GMO Bananas' on us under the pretext of "bio-fortification" without appropriate and adequate testing.

Crop Genetic Diversity is indispensable in providing resilience to face unpredictable environmental and climate changes and meet the needs of an ever expand ing human population.

Source: Seed Freedom Report 2012, Living Seed – Breeding as Co-evolution, Salvatore Cecarelli

The model of industrial agriculture and modern plant breeding has resulted in severe erosion of diversity of crop varieties. The changes in who controls seed production and seed supply have had devastating effects on genetic erosion. Either we can allow the power of diversity to enrich our soils, combat climate change and nourish us from disease to health or we can sit back and allow monocultures, chemicals and GMOs to drive humanity to extinction.

Interdisciplinary science and democratic movements created the momentum for International Environmental law. Science and Democracy continue to be the forces challenging the mindless threat to the Earth because of corporate greed.

In the case of Climate Change the key issue is reduction of emissions and strategies for adaptation. In the case of Biodiversity Conservation the key issues are Biosafety and promotion of practices that conserve Biodiversity.

Both treaties connect in agriculture, our daily bread. How we grow our food has a major impact on the health of the planet and the health of people.

Industrial agriculture is based on fossil fuels and the chemicals it uses are derived from fossil fuels. As I have mentioned in my book "Soil Not Oil" 50% of the atmospheric pollution linked to excess carbon dioxide, nitrogen oxide, methane comes from and industrial, globalised food system. A report from Grain based in Barcelona Spain in their report on Food Sovereignty concludes "that the current global food system, propelled by an increasingly powerful transnational food industry, is responsible for about half of all human produced greenhouse gas emissions: anywhere between a low of 44 per cent to a high of 57 per cent."

Source: www.grain.org/ article/entries/5390-food-sovereignty-can-stop-climate-change-and-feed-us-all.

The same fossil fuel intensive, poison intensive industrial agriculture is also destroying the biodiversity of our seeds and crops, soil biodiversity, killing pollinators, destroying water resources. It is also responsible for 75% of the disease epidemic related to bad food produced by oil.

The spread of monocultures and the increasing use of chemical fertilisers in agriculture, combined with destruction of habitats, have contributed to the loss of biodiversity. Paradoxically, this biodiversity would have helped sequester greenhouse gases.

Industrial agriculture is a major contributor to climate change because of its dependence on chemicals, fossil fuels and on a globalized food system that requires inefficient, energy intensive, long distance transport. Additionally, it is highly vulnerable to climate change as it is based on uniformity and monocultures, on centralized distribution systems, and on intensive energy and water inputs. Genetically Engineered (GE) crops aggravate all the shortcomings of industrial monoculture crops, spreading more genetic uniformity, causing genetic contamination and weakening resilience to biotic and abiotic stresses, all the while requiring more water and pesticides. GE is a false solution and a dangerous diversion from our task of mitigating climate change. The industrial agricultural system, as promoted by the current economic paradigm, has accelerated climate instability and increased food insecurity. The spread of modern, commercial agriculture has been identified as the chief contemporary cause of the loss of genetic diversity and local varieties. The impact of GE on seed diversity as well as on the overall biodiversity will be devastating. Techno-fixes present an attractive "silver-bullet" solution, but will only increase vulnerability while simultaneously undermining nature's and farmers' safeguards against climate chaos.

New research published on 2nd March, 2016 in *The*

*Lancet* finds that by making food less available, climate change could account for more than 500,000 human deaths by the year 2050. The researchers assumed a scenario where global air temperature in 2050 is about 2 degrees warmer than it was between 1986 and 2005. According to the research where agriculture is crippled by more drought, heat, and flooding, each person would see 3.2 percent less food on their plates every day overall. In addition, by 2050, under that same climate change scenario, we can anticipate the average person will eat 4 percent fewer fruits and vegetables.

Source: http://www.newsweek.com/climate-change-leads-500000-deaths-altering-food-production-433182.

The alternative, a biodiversity intensive, ecology intensive, localised food system, rejuvenates the health of the planet, and our health. Through biodiversity of plants fixing atmospheric carbon and nitrogen, excess greenhouse gases are removed from the atmosphere where they cause pollution and climate instability, and are put in the soil where they rejuvenate fertility and produce more and healthier food.

The same food and agriculture systems that conserve and rejuvenate biodiversity also mitigate climate change. They contribute to health and to increased livelihoods in regenerative living economies.

People and communities everywhere are giving up poisons and adopting agroecology. They are shifting from an agriculture destroying the health of the planet and our health to a regenerating healing agriculture. They are obeying the laws of Gaia and waking up to the Rights of Mother Earth, simultaneously enhancing human well being. They are not waiting for governments to trump each other just to see who gets what share of a divided planet. Some governments are also waking up to both their obligations, and with it the possibilities of creating post fossil fuel economies through regenerative agriculture and renewable energies.

Agroecology and Organic farming - working with nature - takes excess carbon dioxide from the atmosphere, where it does not belong, and through photosynthesis, puts it back in the plants and soil, where it belongs. It also increases the water holding capacity of soil, contributing to resilience in times of more frequent droughts, floods and other climate extremes. **Organic farming has the potential of sequestering 10 Gigatons of carbon dioxide, equivalent to the amount needed to be removed from the atmosphere to keep atmospheric carbon below 350 parts per million, and the average temperature increase of 2 degrees centigrade. We can bridge the emissions gap through ecological agriculture now, not at some point in the future, through ecological agriculture, working with nature. We can regenerate life on earth and rejuvenate ecological cycles by growing more living carbon.**

All over the world, small farmers and gardeners are already implementing this agriculture, preserving and developing their soils, their seeds, their traditional knowledge. They are feeding their communities with healthy and nutritious food while preserving the planet. They are thus sowing the seeds of food democracy - a food system in the hands of farmers and consumers, devoid of food miles and plastics.

In the lead up to the Climate Summit in Copenhagen in 2009 I wrote "Soil Not Oil" because the relationship between climate instability and industrial agriculture, and the intimate relationship between soil and oil were missing both in the UN negotiations, as well as in the Climate movements. Our work in Navdanya had shown that indigenous seeds and organic farming contribute in a very significant way to climate resilience. Agroecology, being based on ecological processes, and therefore being free of fossil fuel based chemical inputs, also avoids green house gas emissions, thus contributing to mitigation.

The answers to hunger and poverty, and climate change do not lie in violent minds ignorant of the intelligence and creativity that is abundant in humans and all species. It lies in the recognition that we are intelligent Earth Citizens, and our well being is connected to all other beings. That compassionate thought and action are what create abundance and well being for all, not inconsiderate, careless, violent "smartness". The "precision" of killing does not give birth to life. It results in killing. The Mechanical Mind celebrates violence. The Ecological Mind makes peace with all beings.

The strategic implementation of post-war chemical agriculture has, in the last century, systematically destroyed the diversity that would be our greatest strength in combating the climate crisis created, to a large extent, by this very system of production and consumption of chemical food. In this period we have lost 93% of the varieties of food crops. The loss of this diversity in our diets has led to nutritional deficiencies. Having created these deficiencies by eroding diversity, chemical and biotechnology corporations are

now offering the disease of monocultures as a cure for malnutrition through bio-fortification. Golden Rice is a startling example of the failed, obsolete science being used to impose food slavery on the people of the world. Especially the poorest, from the people of Africa and Argentina to the 300,000 farmers in India who have been driven to suicide by these new age colonisers through royalty collection and destruction of alternative sources of seed.

This is why seed by seed, farmer by farmer, plate by plate, we are sowing an alternative based on intelligence and science, responsibility and awareness, care and compassion. And in the process more species are flourishing, there is more food, more rejuvenation of our biodiversity, our soil, our water, the potential for a healthier planet and society with more knowledge among more people, and an Earth Democracy based on the intelligence of all life evolving in harmony.

This report on **Seeds of Hope, Seeds of Resilience, How Biodiversity and Agroecology offer Solutions to Climate Change** synthesises 3 decades of Navdanya's work on Biodiversity Conservation and Agroecology as solutions to Climate Change.

For more than 3 decades Navdanya has been sowing Seeds of Hope and Seeds of Resilience. Our work with communities across India to conserve Biodiversity and practice Agroecology based on Biodiversity intensification shows that not only can we address climate change and rejuvenate the planet, one seed at a time, in so doing we produce more and better food which could provide enough nourishment for two times the world population.

Navdanya's work on climate change shows that efforts that mitigate climate change not only contribute to adaptation but also contribute to climate and ecological justice. Our three areas of focus are –

- Climate Change and Biodiversity Conservation, including saving and exchanging Climate Resilient Farmers Varieties of Seeds
- Climate Change and Agroecology &
- Climate Change in the Himalaya

Navdanya is dealing with the issue of Climate Change directly with the farmers through participatory research. Recently Navdanya published "Climate Change at the Third Pole" a synthesis of participatory studies by communities and research papers of various scientists working in Himalayan region from Tibet, Ladakh, Himachal to Uttarakhand as. Navdanya also released a small documentary on climate change. Other than this Navdanya is also conserving climate resilient crops and varieties in its community run seed banks across the country. We have also undertaken long term studies comparing soils of chemical farms and organic farms, which shows that not only is organic farming improving soil fertility and soil health, thus increasing food production, but it also reverses climate change.

# 2

# The Climate Crisis: Transgressing Planetary Boundaries, Disrupting Ecological Cycles

Climate chaos, climate instability, climate change are the most dramatic expressions of the human impact on planet earth. While the earth's own climate has gone through various stages of warming and cooling, the present trend towards warming, and the related destabilization of climate systems and weather patterns is human induced and it is human beings who are already suffering the impact of intensification of drought, floods, cyclones and hurricanes, the melting of snow and ice and the aggravation of the water crisis. Tragically it is those who have contributed the least to green house gas emissions who are suffering the most because of climate chaos - communities in the high Himalayas who have lost their water resources as glaciers melt and disappear, peasants in the Ganges basin whose crops have failed because of drought, coastal and island communities who face new threats of sea level rise and intensified cyclones.

The linear extractive agriculture system based on fossil fuels is rupturing ecological processes and planetary boundaries. The three boundaries where we have already crossed safe limits are Biodiversity Integrity and Genetic Diversity, and the biochemical nitrogen and phosphorous cycles. All three overshoots are rooted in the chemical intensive, fossil fuel intensive industrial model of agriculture.

Erosion of genetic diversity and the transgression of the nitrogen boundary have already crossed catastrophic levels. Industrial agriculture has contributed to both.

Industrial chemical agriculture is based on external inputs of nitrogen, phosphorous and potassium, and on industrial monocultures of globally traded commodities. The latter is destroying biodiversity, the former are disrupting the nitrogen and phosphorous cycles.

Industrial monocultures are an important driver of destruction and erosion of biodiversity, both in forests and farms. The Amazon and the Indonesian rainforests are being destroyed for growing monocultures of Roundup Ready Soya and Palm oil.

We used to eat 10,000 plant species. Today, just 12 globally traded commodities are being grown. (Navdanya, The Law of the Seed). Only 10% of the corn and soya is used as food. The rest goes to produce biofuels and animal feed.

While using 75% of the land, industrial agriculture based on fossil fuel intensive, chemical intensive monocultures produce only 30 % of the food we eat, while small, biodiverse farms using 25% of the land provide 70% of the food. At this rate, if the share of industrial agriculture and industrial food in our diet is increased to 45%, we will have a dead planet. There will be no life, no food, on a dead planet. That is why rejuvenating and regenerating the planet through ecological processes has become a survival imperative for the human species and all beings. Central to the transition is a shift from fossil fuels and dead carbon, to living processes based on growing and recycling living carbon.

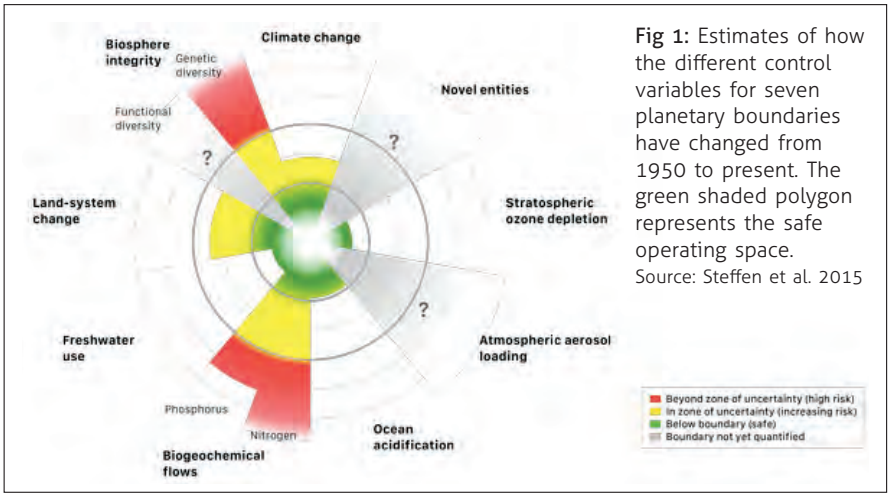



Fig 1: Estimates of how the different control variables for seven planetary boundaries have changed from 1950 to present. The green shaded polygon represents the safe operating space.
Source: Steffen et al. 2015

## 2.1 Dead Carbon vs Living Carbon: Fossil Fuel Based Industrial Agriculture rupturing the Carbon Cycle vs Agroecology Regenerating the Living Carbon Cycle

Life on Earth depends on the Living Economy of the Seed, the Soil, the Sun. And all the needs of humans and other animals are provided sustainably within this living economy.

As Sir Albert Howard writes in the Agriculture Testament,

> "The energy for the machinery of growth is derived from the sun, the chlorophyll in the green leaf is the mechanism by which this energy is intercepted; the plant is thereby enabled to manufacture food-to synthesise carbohydrates and proteins from the water and other substances taken up by the roots and the carbon dioxide of the atmosphere. The efficiency of the green leaf is therefore of supreme importance: on it depends the food supply of the planet, our well being, and our activities. There is no alternative source of nutriment. Without sunlight and the green leaf our industries, our trade, our possessions would soon be useless".

The seed with the blessings of the sun, grows into the plants that become the green mantle of the earth, returning part of plants to the soil as organic matter to create living soil, and providing humans and all beings with all their needs for food, clothing, shelter.

### The Carbon cycle

The main entry of Carbon (C) into the biosphere is through the process of photosynthesis or gross primary productivity (GPP) that is the uptake of C from the atmosphere by plants. Part of this C is lost in several processes: through plant respiration (autotrophic respiration); as a result of litter and soil organic matter (SOM) decomposition (heterotrophic respiration) and as a consequence of further losses caused by fires, drought, human activities etc. Climate change may lead to ecosystem degradation; limiting the capacity to sequester C. Global warming could lead to an increase in heterotrophic respiration and decomposition of organic matter in soil. A soil C balance is presented as Fig. 1. Carbon stock may be very useful tool until other acceptable and environmentally friendly alternatives are found of reducing dependence on fossil fuel.

To ascertain the role of organic farming in mitigation of impact of climate change Navdanya did a study in 4 different agroecological zones of India and studied several parameters including water holding capacity, soil carbon buildup, carbon sequestration, microbial biomass, microbial activity, enzyme activities, effect on crop and cropping system, soil physical properties and soil organic C stabilization and loss. Case studies on paddy and sugarcane were also done in Uttarakhand which further reconfirmed the benefits of organic farming over chemical farming in each and every place.

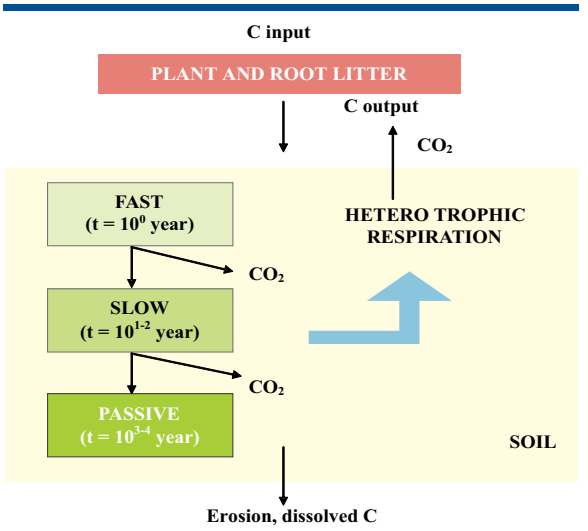



Fig 2: Soil carbon balance

### Regenerating Living Carbon in the Soil through Organic Farming

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by the soil microbes as the decay occurs. Such material is continually being broken down and resynthesized by soil microorganisms. Consequently, organic matter (soil carbon) is a rather transitory soil constituent, lasting from a few hours to several hundred years. This constituent required maintenance by the regular addition to the soil of plant and/or animal residues. To get rid of adverse effect from climate change maintenance of soil carbon is very important and can be done only by organic agriculture.

Increase in total carbon build up due to organic farming than chemical farming was studied under different agro-ecosystems. The result showed an additional increase of 62.5 to 83 µg $g^{-1}$ soil carbon in organic agriculture (Table 1) irrespective of the crop growth. In general, the carbon build up was more under humid agro-ecosystems. The additional C build up was more under organic agriculture would definitely help in better environment in soil for microbial growth,

nutrient recycling and moisture retention of the soil. It also helps in reduction of soil erosion especially under arid and semi-arid areas.

**Table 1: Increase in C build up due to organic agriculture***

| Ecozones | Additional increase (µg g-1) | |
|---|---|---|
| | Range | Mean |
| Arid | 49-83 | 62.5 |
| Semi-arid | 57-98 | 71.9 |
| Sub-humid | 61-101 | 75.5 |
| Humid | 68-102 | 83.0 |

*average of 10 farms in each agro ecosystems

The relationship between living seed, **living soil, and the life giving sun is the cycle of living carbon. Living carbon is very different from dead, fossilised carbon.**

The extraction of fossil fuels(dead carbon) from the earth, burning it, and putting uncontrollable emissions into the atmosphere is the rupture of the carbon cycle, and through it a destabilisation of climate systems.

All the coal, petroleum, natural gas we are burning and extracting was formed over 600 million years. We are annually burning up 20 million years of nature's work annually.

Source: Project Sunshine: How science can use the sun to fuel and feed the world Steve McKevitt, Tony Ryan

This is why the carbon cycle is broken.

But dependence on dead fossil carbon is also responsible for creating scarcity in living carbon, which reduces availability of food for humans and for the soil organisms. This scarcity translates into malnutrition and hunger on the one hand and desertification of the soil on the other. Chemical agriculture intensifies chemicals and capital inputs, while reducing the biodiversity, biomass, and nutrition that the seed, the soil, the sun can produce.

To fix more living carbon from the atmosphere, we need to intensify our farms and forests biologically, in terms of both biodiversity and biomass. Biodiversity and biomass density produces more nutrition and food per acre as we have sown in the Navdanya report "Health per Acre", thus addressing the problem of hunger and malnutrition. It also increases not just the living carbon in the soil, it increases all other nutrients and the density of beneficial organisms.

**The soil on Navdanya's Organic Farm in Doon Valley has increased soil organic matter by 100%. Soil organic matter is now 2.2 tonnes per ha.**

Organic farming - working with nature - takes excess carbon dioxide from the atmosphere, where it doesn't belong, and through photosynthesis, puts it back in the soil where it belongs. It also increase the water holding capacity of soil, contributing to resilience in times of more frequent droughts, floods and other climate extremes. Organic farming has the potential of sequestering 10 Gigatons of carbon dioxide, equivalent to the amount needed to be removed from the atmosphere to keep atmospheric carbon below 350 parts per million, and the average temperature increase of 2 degrees centigrade. We can bridge the emissions gap through ecological agriculture now, not at some point in the future, through ecological agriculture, working with nature.

And the more biodiversity and biomass we grow, the more the plants fix atmospheric carbon and nitrogen, and reduce both emissions and the stocks of pollutants on the air. Carbon is returned to the soil through plants. That is why the connection between biodiversity and climate change is an intimate connection.

The more the biodiversity and biomass intensification of forests and farms, the more organic matter is available to return to the soil, thus reversing the trends towards desertification, which is the primary reason for displacement and uprooting of people and the creation of refugees (Source: Navdanya Manifesto Terra Viva : Our Soils, our Commons, our Future)

To repair the broken carbon cycle we need to turn the seed, the soil the sun to increase the living carbon in the plants and in the soil. We need to remember that living carbon gives life, dead fossil carbon is disrupting living processes. That with our care and consciousness we can increase living carbon on the planet, and increase the well being of all. The more we grow it, the more we have. On the other hand, the more we exploit and use dead carbon, more pollution we create, and the less we have for the future. Dead carbon must be left underground. This is an ethical obligation and ecological imperative.

This is why the term "decarbonisation" without qualification and distinction between living and dead carbon is scientifically and ecologically inappropriate. If we decarbonised the economy, we would have no plants, which are living carbon. We would have no life on earth which creates and is sustained by living carbon. A decarbonised planet would be a dead planet.

We need to Recarbonise the world with Living Carbon.
We need to decarcarbonise it of dead carbon.

# Regenerating the Earth by Growing Living Carbon

## THE CARBON WHEEL

The photosynthesis deposits its carbon wealth in the soil. Continuous building up of the carbon pool in the lithosphere is the very essence of photosynthesis. This deposit of "carbon wealth" does not lie inert. It becomes the very basis of terrestrial life, both within and above the soil. The whole life on Earth, in fact, flowers on the carbon pool of the lithosphere. We can call this dynamic lithosphere carbon pool as the "Carbon Wheel".

A wheel is a potent symbol of progress, hope and happiness. So is the Carbon Wheel with its vital attributes to life. These attributes represent "spokes" of the Carbon Wheel. Photosynthesis constructs the Carbon Wheel when carbon dynamically moves from its atmospheric pool to all varieties of life, via green vegetation, finally making its deposits in the lithosphere. More the free atmospheric carbon enters into life via photosynthesis, more constructive the Carbon Wheel becomes. When the phenomenon of photosynthesis is obstructed to certain extent, the Carbon Wheel gets its "spokes" broken and more of the carbon emits back to the atmosphere to assume its destructive role – of global warming and subsequent climate change. This is what is happening in our contemporary times. When "spokes" of the Carbon Wheel are intact, that is when the carbon is bound in the lithosphere, the wheel goes stronger, moves on in balance, and carbon writes its creative stories.

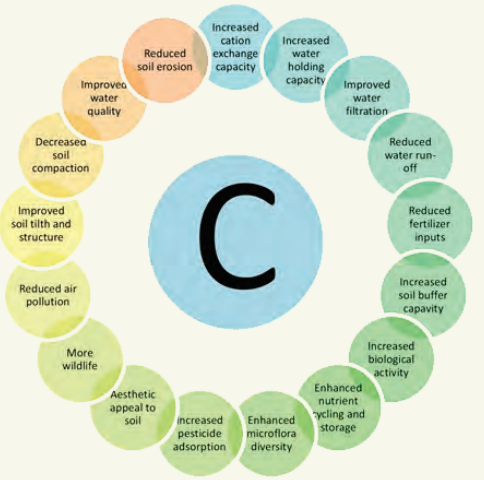



Fig. 3: The Carbon Wheel: Fed by photosynthesis, it keeps going and our environment keeps stabilizing, our biosphere stays healthy, our climate spells its benevolence, humanity reverberates with hopes and happiness, and our future sustains in the mode of sustainability (some ideas have been derived from Reicosky 2007)

The Carbon Wheel of the lithosphere has its constructive impression on whole of the biosphere, weaving life everywhere. It keeps moving within the lithosphere and it goes building up pathways to humanity's material and cultural progress. It keeps moving in the lithosphere and it upholds the Living Planet into balance, and into sustainability. The Carbon Wheel of the lithosphere keeps moving on and the cosmos goes on writing its mysterious story of Evolution.

On Earth the cosmic Evolution flowers with Photosynthesis. All of the existing and continuously evolving species, and all of humankind are the beautiful flowerings of this Evolution.

*Whatever we see, smell, hear, touch and feel*
*Is all on account of photosynthesis.*
*Whatever we conceive and cultivate within*
*Is all owing to photosynthesis.*
*Myriad colours in nature,*
*All varieties of life,*
*All breathtaking ecstasies and*
*The beauty infinite that we witness –*
*Are all the lively gifts of photosynthesis.*
*We – the humans – have evolved*
*As custodians of the biosphere*
*Which was an indomitable will*
*Of photosynthesis.*
*All evolution on Earth*
*Is a benevolence of photosynthesis.*
*Photosynthesis smiles on us*
*For we are the most wonderful beings of it.*
*So wonderful that photosynthesis generated*
*A unique consciousness in us*
*And we were evolved*
*As guardians of photosynthesis itself.*
*Our hands cannot be cruel,*
*We cannot enslave the phenomenon*
*That controls the climate*
*Of our own destiny.*
*Let us awaken to the consciousness*
*Of benevolence*
*That photosynthesis deeply ingrained in us –*
*Let us liberate photosynthesis,*
*Let us give it back its full freedom,*
*Let us help it prevail with its all potencies*
*And then we shall also prevail*
*Amidst a climate*
*That showers its benevolence*
*Upon us*
*To help us*
*Prevail with all the glory and happiness*

## 2.2 Fossil Fuel Based Synthetic Fertilisers and Transgression of the Nitrogen Boundary

The last century has witnessed the emergence of fossil fuel based, chemical based industrial agriculture. All chemicals used in industrial agriculture are based on fossil fuels. As I have written in Soil Not Oil, fossil fuel based agriculture is the biggest contributor to climate change, accounting for 40-50% green house gas emissions.

Besides the carbon dioxide directly emitted from fossil fuel agriculture, nitrous oxide is emitted from nitrogen fertilisers based on fossil fuels, and methane is emitted from factory farms and food waste.

Nitrous oxide is 300 times more disrupting for the climate than carbon dioxide. Nitrogen fertilisers are not just destabilizing the climate, they are creating dead zones in the oceans, and desertifying the soils. In the planetary context, erosion of biodiversity and the transgression of the nitrogen boundary are serious crisis. These aspects of the eco logical crisis are usually ignored.

When the factories that produced explosives by fixing atmospheric nitrogen by burning fossil fuels at high temperature could also be used for making synthetic fertiliser, it was said we will now produce Bread from Air.

Synthetic fertilisers are part of a fossil agriculture and food system which accounts for 50% greenhouse gas emissions leading to climate change. Nitrogen fertilisers lead to emissions of Nitrogen oxide which is a green house gas that contributes 300 times more to global warming than carbon dioxide. They also increase water demand in agriculture and are responsible for "Dead Zones" in oceans and waterways. Reducing synthetic nitrogen use slightly on large farms, while forcing more small farmers off the land or into seed and data slavery is not the real response to reducing use of chemicals. We do not need the artificial fertilisers at all.

Synthetic nitrogen fertilisers are based on fossil fuels and use the same process that also made explosives and ammunitions for Hitler during World War II. Synthetic nitrogen fertiliser were promoted in agriculture after World War II when large stocks of leftover ammonium nitrate munitions were marketed for agricultural use. The energy intensive Haber Bosch process uses natural gas to artificially fix nitrogen from the air at high temperature and produce ammonia. Ammonia is the feedstock for all synthetic nitrogen fertilisers as well as for explosives.

The manufacture of synthetic fertilizer is highly energy-intensive. One kg of nitrogen fertiliser requires the energy equivalent of 2 litres of diesel. Energy used during fertiliser manufacture was equivalent to 191 billion litres of diesel in 2000 and is projected to rise to 277 billion in 2030. This is a major contributor to climate change, yet largely ignored. One kilogram of phosphate fertilizer requires half a litre of diesel. (Shiva, Soil Not Oil 2008).

Since synthetic fertilisers are fossil fuel based, they contribute to the disruption of the carbon cycle. But they also disrupt the nitrogen cycle. And they disrupt the hydrological cycle, both because chemical agriculture needs ten times more water to produce the same amount of food than organic farming, and it pollutes the water in rivers and oceans.

Pulses fix nitrogen non violently in the soil, instead of increasing dependence on synthetic fertilisers produced violently by heating fossil fuels to 550 degrees centigrade. Chick-pea can fix up to 140 kg nitrogen per hectare and pigeon-pea can fix up to 200 kg nitrogen per hectare that fix nitrogen non violently.

Returning organic matter to the soil builds up soil nitrogen. A recent study we are undertaking shows that organic farming has increased nitrogen content of soil between 44-144 %, depending on the crops.

Since war expertise does not provide expertise about how plants work, how the soil works, how ecological processes work, the potential of biodiversity and organic farming was totally ignored by the militarised model of industrial agriculture.

Ever since the advent of Green revolution in 1960s, Government has adopted a policy to support chemical fertilizers through a subsidy system. The amount of subsidy on synthetic N-P-K fertilisers (domestic and imported) in India during the last three decades has grown exponentially from a mere Rs. 60 crore during 1976-77 to an astronomical Rs. 40,338 crore during 2007-08. In 2009 it shot up to Rs 96,606 crores. However subsidy on fertilizer for the year 2015-16 is planned to be Rs. 72968.56 crore.

1. Fertilizer response has dramatically reduced. Sharma and Sharma (2009) mentioned about the declining fertilizer response for the last thirty years from 13.4 kg grain kg nutrient in 1970 to 3.7 kg grain

kg nutrient in 2005 in irrigated areas. According to Biswas and Sharma (2008) while only 54 kg NPK / ha was required to produce around 2 t /ha in 1970, around 218 kg NPK/ha was used in 2005 to sustain the same yield.

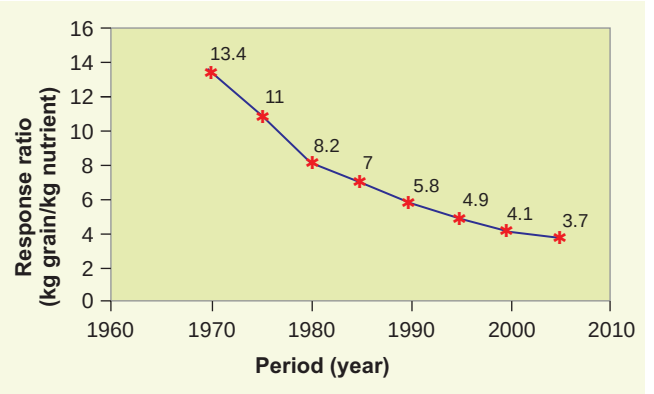



**Fig 4:** Fertiliser response of foodgrain crops in irrigated areas in India
Source: Biswas and Sharma 2008

From the 90s, there has been a debate in the policy, academic and civil society circles on the ill effects of Chemical Fertilizers on soil health and food security. Government of India acknowledges the problem only in 2009, when then Union Finance minister Sri Pranab Mukherji in Parliament during his budget speech said, *"In the context of the nation's food security, the declining response of agricultural productivity to increased fertilizer usage in the country is a matter of concern. To ensure balanced application of fertilizers, the Government intends to move towards a nutrient based subsidy regime instead of the current product pricing regime…"*

2. Chemical fertilizers are destroying the soil food web and the living organisms that create soil fertility, soil aggregates and help conserve water in the soil. Industrial agriculture therefore contribution to desertification and increasing drought, affecting food security, livelihood security as well as making agriculture more vulnerable to climate change.

As per the FAO- Healthy Soils are the foundation for food, fuel, fibre and even medicine. So we definitely need healthy soils for growing healthy food as well as healthy environment.

According to the Soil Association in order to tackle the issues and challenges and to achieve the UN Sustainable Development Goals of environmental sustainability and eradication of extreme poverty and hunger, food and farming systems which put local needs first and which follow organic and sustainable agriculture principles are key.

Year 2015 was celebrated as Year of Soil. Government of India also had a major focus on soil health. In fact, the Organic program of the Government of India has been absorbed into the soil health program.

But unfortunately even today there is lack of awareness amongst the people about the soil health for most of the people soil health is NPK, But soil is much more; soil is basically a Living System. There is need of creating awareness about the soil health and soil food web, which will help different stakeholders and people working in the field of soils including farmers and students to enhance their knowledge and understanding about the soils and soil health. Today what is needed is to understand the basic principle for improvement of soil health i.e. instead of feeding the plant directly, one should nourish the soil. Biodiversity based organic farming based on local resources and farmers' indigenous knowledge is the best solution.

Chemical fertilisers are leading to a decline in productivity because they are destroying soil health. During three and half decades fertiliser productivity has declined from 48 kg food grains/kg NPK fertiliser in 1970-71 to 10 kg food grains/kg NPK fertiliser in 2007-08

Source: Aulakh, M.S. and Benbi, D.K. 2008. Enhancing fertilizer use efficiency. In Proceedings of FAI Annual Seminar 2008, 4-6 December, 2008. The Fertilizer Association of India, New Delhi, India.pp. SII-4 (1-23).

Subba Rao, A. and Reddy, K.S. 2009. Implications of soil fertility to meet future demand: Indian scenario. In Proceedings of the IPI-OUAT-IPNI International Symposium on Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages, Vol. 1 (Eds. MS Brar and SS Mukhopadhyay), 5-7 November 2009. IPI, Horgen, Switzerland and IPNI, Norcross, USA.pp. 109-135.

Integrating pulses in organic agriculture is the only sustainable path to food and nutritional security. This is the integration of life and the intensification of ecological processes, not the integration of power and intensification of chemicals, capital and control.

Pulses are truly the pulse of life for the soil, for people and the planet. In our farms they give life to the soil by providing nitrogen. This is how ancient cultures enriched their soils. Farming did not begin with the green revolution and synthetic nitrogen fertilisers. Whether it is the diversity based systems of

India-Navdanya, Baranaja, or the three sisters planted by the first nations in North America, or the ancient Milpa system of Mexico, beans and pulses were vital to indigenous agroecological systems.

As Sir Albert Howard, known as the father of modern agriculture, writes in The Agriculture Testament, comparing agriculture in the West with Agriculture in India:

> "Mixed crops are the rule. In this respect the cultivators of the Orient have followed Nature's method as seen in the primeval forest. Mixed cropping is perhaps most universal when the cereal crop is the main constituent. Crops like millets, wheat, barley, and maize are mixed with an appropriate subsidiary pulse, sometimes a species that ripens much later than the cereal. The pigeon pea (cajanusindicus), perhaps the most important leguminous crop of the Gangetic alluvium, is grown either with millets or with maize…
>
> Leguminous plants are common. Although it was not until 1888, after a protracted controversy lasting thirty years, that Western science finally accepted as proved the important role played by pulse crops in enriching the soil, centuries of experience had taught the peasants of the east the same lesson."
>
> Source: Sir Albert Howard. An Agricultural Testament. pg 13

Vegetable protein from pulses is also at the heart of a balanced, nutritious diet for humans. The Benevolent Bean is central to the Mediterranean diet. India's food culture is based on "dal roti"and "dal chawal". Urad, moong, masoor, chana, rajma, tur, lobia, gahat have been our staples. India was the largest producer of pulses in the world. And our proteins are rich in nutrition, delicious in taste.

Pulses have been displaced by the Green Revolution monoculture, and now the spread of monocultures of Bt cotton and soya.

11.6 million hectares (mh) were planted with Bt in 2014.

Source: http://indianexpress.com/article/india/india-others/india-worlds-4th-in-gm-crop-acreage-well-ahead-of-china/#sthash.yqifpgcS.dpu

If pulses had been planted on half this land we would have had an additional 4 million tonnes of pulses available.

12.12 million ha were planted under soya in 2014

Source: http://economictimes.indiatimes.com/news/economy/agriculture/indian-farmers-could-plant-record-soybean-area-as-prices-rally/articleshow/35474629.cms

This area earlier grew pulses. We are therefore growing nearly 10 million tonnes less pulses.

Further, under the new private partnership of the government of Maharashtra with ADM, farmers are receiving half the MSP.

Source: http://www.ficci.com/spdocument/20539/SOYBEAN-Report.pdf

## 2.3 Recurrent Climate related Disasters posing serious threats to Agriculture and Biodiversity

Climate change is not just a problem for the future. It is impacting us every day, everywhere. Climate change has resulted in an increase in droughts, floods, and tropical cyclones- what are known as "extreme events". This increase has already begun. Extreme droughts, extreme floods, and extreme cyclones are part of the destabilization of the climate due to greenhouse gases.

The snowfall period in the mountains has shrunk by 8 to 10 days in the past 10 years and snowfall has become intermittent. Monsoon rains have become quite erratic and winter rains are now not only scarce but are quite erratic. Extended summers in the high mountainous regions are changing the ecology of the region.

The intensity and frequency of hurricanes and cyclones is increasing. Asia was hit by the Odisha super cyclone in 1998; it killed 30,000. In November 2007, Cyclone Sidr hit Bangladesh with wind speeds of 260 kilometers per hour; it killed 4,400 and displaced 4 million. In May 2008, Cyclone Nargis devastated Myanmar. At least 84,537 people were killed and another 53,836 went missing. The intensity of Hurricane Katrina, which devastated the Gulf Coast in August 2005, is also linked to climate change. The higher the speed of a cyclone, the more destructive is its force. Globally, category 4 and 5 storms were 50 percent more frequent between 1990 and 2004 than they were between 1975 and 1989.

In 2003, a heat wave in August led to the deaths of 50,000 people in Europe, including 13,000 in France. Nine hundred died in England, more than 1,300 in Portugal, 8,600 in Spain, 4,600 in Netherlands, and 1,000 in Germany and Switzerland. Italy, which initially reported 8,000 deaths, later raised its death toll to 20,000

In January 2008, unprecedented snowstorms crippled China. Sixty centimeters of snow covered parts of Xinjiang. More than 100,000 people were evacuated after their homes collapse under heavy snow. Temperatures plummeted to 43 degrees below zero Celsius. Twenty –one people died; 5,000 people were treated for frostbite.

Extreme events like heavy rains, cloud burst, cyclones etc. have grown both in number and intensity in India in the space of half a century. An analysis of rainfall during monsoon season from 1951 to 2000 in an area of about 1.4 million square kilometers in Central India shows that episodes of "heavy" rainfall (10 centimeters or more of rain in a single day) had increased at the rate of 10 percent per decade. Instances of "very heavy" rainfall (15 centimeters of more of rain in a day) more than doubled between 1951 and 2000. In addition, the average intensity of the four heaviest rain events during each monsoon had grown from 18 centimeters in 1951 to 26 centimeters in 2000. These empirical tends have been modeled by the Pune – based Indian Institute of Tropical Meteorology and they fit with climate change projections.

In the year 2006 intense rain claimed several hundred lives in Jaisalmer and Barmer districts of Rajasthan. In the month of August 2010, Leh, Jammu and Kashmir witnessed 'cloud burst' where at least 225 were dead. In the year 2013, four border districts of Uttarakhand state received more than 400% rainfall in a span of three days from 15th till 17th June, which killed about 20,000 people and resulted in huge damage to property, houses and crops.

Phailin, a Severe Cyclonic Storm as powerful hurricane Katrina, devastated Odisha in the month of October 2013 causing substantial damage in parts of Andhra Pradesh. Phailin is believed to be the most intense cyclone that crossed Indian coast after the 1999 Odisha Super Cyclone. More than 12 million people had been hit by the gale in 17968 Villages across 17 districts. Phailin rendered 3.7 lakh people homeless. About 3.6 million hectares of cultivable land, 0.5 million was badly affected causing damage of more than Rs. 2400 crore to kharif paddy. It also damaged 7500 telephone towers.

In September, 2014, floods and rain in Jammu and Kashmir claimed more than 300 lives, affected about 1.25 million people and damaged nearly three lakh houses in the state. The loss to the state economy was estimated to be about one lakh crore. More than 300 ninety thousand animals were also perished. Rain broke the previous records of the state by receiving more than double rainfall in short span of time. The flood is reported as the worst in 110 years.

In October 2014, Cyclone Hudhud wreaked havoc in four districts of Andhra Pradesh, Vishakhapatnam, Srikakulam, Vizianagram and East Godavari. As per the state government figures about 2.48 lakh people were affected killing 144 people. It caused loss of more than 21000 crore to public property. Agriculture loss was about Rs. 2000 crore. More than 1 lakh houses were damaged.

The 2015 Gujarat cyclone (Deep Depression ARB 02) in June 2015 brought heavy rains to the state of Gujarat that resulted in floods. The floods resulted in at least 80 deaths. The wild life of Gir Forest National Park and the adjoining area was also affected.

The heavy rainfall during November–December 2015 badly affected the Coromandel Coast region of the South Indian states of Tamil Nadu and Andhra Pradesh, and the union territory of Puducherry. The city of Chennai particularly hard-hit and more than 500 people were killed and over 18 lakh (1.8 million) people were displaced. Damages and losses estimated to be ranging between Rs. 50000 crore (US$7 billion) to Rs.100000 crore (US$15 billion)

Source: https://en.wikipedia.org/wiki/2015_South_Indian_floods

https://en.wikipedia.org/wiki/2015_South_Indian_floods - cite_note-sunkmonday-11

Heavy rains in July 2015 Gujarat was affected by the flood by killing at least 72 deaths and over 81,609 cattle in three districts; Banaskantha, Patan and Kutch. The property worth Rs 2000 crore was completely damaged or washed away as per government estimate. The crops in about 2 lakh hectares failed. In three days Kutch and Banaskantha district recorded over 100 per cent of annual average rainfall, whereas in some areas like Suigam, recorded 510 per cent of the total annual average rainfall.

In the month of August 2015 by heavy rainfall floods were triggered through the river Brahmaputra and its tributaries in Assam and Arunachal Pradesh state. The floods affected 1.65 million people in 21 districts as a result 42 people died. Flooding caused numerous landslides and road blockages affecting 2,100 villages and destroyed standing crops across an area of 180,000 hectares (440,000 acres).

# 3

# Soil Not Oil: Agroecology and Organic Farming as Climate Solutions

Today both planet and people are facing the converging threats of climate change, natural resource depletion and ecosystem collapse. Industrial agriculture, which is supplanting the traditional forms of agriculture that have sustained human civilization for thousands of years, is a major contributor to the threats like climate change, depletion of natural resources like soil, water and biodiversity.

Agriculture means the culture of taking care of the land. Unfortunately, industrial chemical agriculture has destroyed soil fertility; depleted the water holding capacity of soil; destroyed the biodiversity that provides food and nutritional security and protects the soil and contributed to 40% of the Green House Gases that are causing climate change.

Chemical fertilizers are destroying the soil food web and the living organisms that create soil fertility, soil aggregates and help conserve water in the soil. Industrial agriculture therefore contributes to desertification and increasing drought, affecting food security, livelihood security as well as making agriculture more vulnerable to climate change.

Soil provides the basis of all plant, animal and human life on Earth. A healthy soil supports plant growth, has the ability to purify air and water and safeguards animal and human health. One cannot imagine about food without soils. There can't be healthy food without healthy soils. Soils are vital for any ecosystem that plays a key role in the carbon cycles, storing and filtering water, improving resilience to different climatic conditions like floods and droughts etc.

After oceans, soil is the second largest carbon sink on the planet. Soil can nourish carbon-based plants and maximize carbon fixation while minimizing the release of CO2, reversing the effects of climate change. All of these benefits are dependent on the small fraction of soil inhabited by living organisms that comprise the soil food web. A fossil fuel driven economy, including industrial agriculture, has increased the concentration of carbon dioxide in the atmosphere to levels which are triggering climate instability and climate chaos.

Industrial agriculture destroys rural livelihoods and displaces rural communities, contributing to unemployment, economic insecurity, and making society vulnerable to conflicts and violence. In addition costs of production, which includes hybrid and genetically engineered seeds, chemicals and irrigation etc., are increasing with every season pushing farmers into the debt trap and to suicides. More than 300000 farmers have given their life in last two decades because of the debt in India alone.

In the recent years **incidences of climate extremes and climate disasters have increased many fold. Climate resilience has become an economic, ecological and social imperative**.

Other than climate disasters, socioeconomic disasters are also increasing year after year. **Not only diversity of crops but productivity of land has also decreased substantially in last 4 decades due to excessive use of chemical fertilizers**.

A study done by Navdanya in four states of India representing diverse agroecosystems - Uttarakhand, Sikkim, Kerala and Rajasthan (Shiva & Pandey Biodiversity Based Prodyuctivity, An Alternative paradigm for Food Security 2006) comparing the monoculture and Biodiversity farms clearly shows that Biodiversity based organic farming system is a better choice over the monoculture farming system not only for the productivity and returns but also for climate resilience.

Navdanya's research in 4 different agro-ecosystems namely - arid agro-ecosystems Western Rajasthan; Semi-arid agro-ecosystems - East–South Rajasthan; Humid agro-ecosystems in Uttaranchal Sub-humid

agro-ecosystems (Vidarbha) India proves that organic farming not only helps sequester upto 25% more carbon, in addition study results clearly showed 5-7% increase in water holding capacity, 15.8 - 17.6% increase in microbial biomass and also helped rejuvenate soil by enhancing the soil microbial activity upto 63% (Shiva and Tarafdar 2009). The study also confirms the significant changes in soil beneficial enzymes (phosphatases, phytase, nitrogenase) due to organic farming.

The major benefit due to organic farming under paddy cultivation in Uttarakhand observed during the study was significant increase in water holding capacity of the soil; organic C, available P and K build up.

Another comparative study of soil microbes and nutrients both in chemical and organic farming was done by Navdanya in 2015-16. (Appendix) To understand the soil health under continuous cultivation after using organic and chemical inputs, a survey was conducted in different states namely: Uttarakhand including Navdanya farm and surrounding villages, Balasore district in Odisha, Banda district in U.P., Ajmer district in Rajasthan and Vidharba in Maharashtra where farmers were selected who were practicing both chemical and organic inputs under different crops at least more than 5 years.

Detailed study of the effect of most important crops on biological parameters like bacteria and fungi population and physico-chemical parameters like Organic matter, Total Nitrogen and available P and K was done in the few crops growing in Uttarakhand i.e. wheat, potato, garlic, mustard, chick pea, chilli and pumpkin is given below. The microbial population especially fungi, bacteria, was significantly higher under organic farming areas than chemical farming. There was reduction in organic matter content of the soil under all the crops growing in chemical farming whereas increase in organic matter content under organic farming soil varies between 26-99%. A significantly higher total N and available K content were observed under organic farming practice. The results clearly showed that organic farming has a great role to maintain excellent soil health and nutrient content in the soil.

It was also observed that continuous chemical farming leads to decline in organic matter, soil macro and micro-nutrients, resulting in a decline in the nutrition content of our food. Effect of continuous farming on soil under organic and chemical farming systems is described below in Table 2 and Fig 5.

Healthy soils are full of biodiversity. 1 gm of soil organic soil contains 30,000 protozoa, 50,000 algae, 400,000 fungi. One tea spoon of living soil contains 1 billion bacteria which translate to 1 tonne per acre. One square cubic metre of soil contains 1000 earth worms, 50,000 insects, 12 trillion roundworms.

Humus, which is the Latin word for living soil, is also the root of "human". We are connected to the soil. When soils are heathy, societies are heathy. When soils are sick and desertified, societies become sick.

Desertification of the soil is related to not returning organic matter to the soil. Soils rich in humus can hold 90% of its weight in water. Living soils are the biggest reservoir of both water and nourishment.

Healthy soils produce healthy plants. When the soil is healthy, with diversity of living organisms, it is able to produce all the nourishment it needs, and all the nourishment plants need.

On the Navdanya farm, organic matter has increased upto 99%, Zn has increased 14 %, Mangnesium has increased 14%. We did not add these as external inputs. They have been produced by the billions and millions of soil microorganisms that are in living soils. Healthy soils produce healthy plants. Healthy plants are then able to nourish humans.

On the other hand, chemical farming has led to decline in soil nutrients, which translate into a decline in the nutrition content of our food.

**Table 2: Showing effect of continuous farming on Soil under Organic and Chemical mode**

| Nutrient | Change under Chemical Farming | Change under Organic Farming |
|---|---|---|
| Organic Matter | -14% | +29-99% |
| Total Nitrogen (N2) | -7-22% | +21-100% |
| Available Phosphorous (P) | 0% | +63% |
| Available Potassium (K) | -22% | +14-84% |
| Zinc (Z) | -15.9-37.8% | +1.3-14.3% |
| Copper (Cu) | -4.2-21.3% | +9.4% |
| Manganese (Mn) | -4.2-17.6% | +14.5% |
| Iron (Fe) | -4.3-12% | +1% |

**Fungi population:** The fungi population on different crops was increased over control soil between 6 and 36 fold when organic farming was practiced, which was much less under chemical farming (2.5-49.7%).

**Bacteria population:** Organic farming enhances bacteria population between 1.8-6.2 fold under different crops, which showed 78% more build up than chemical farming.

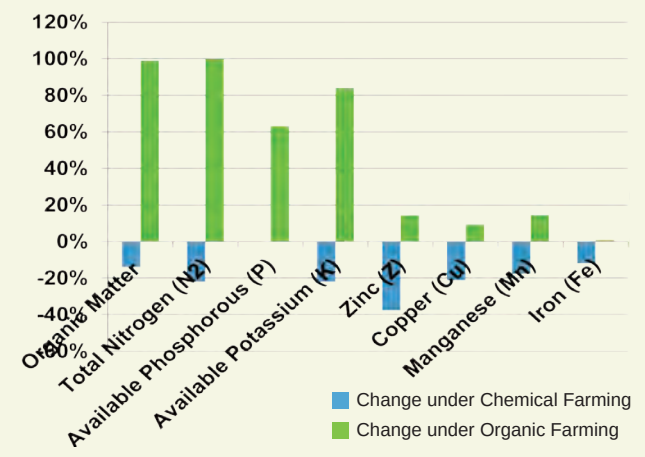



**Fig 5:** Showing effect of continuous farming on Soil under Organic and Chemical mode

## 3.1 Biodiversity Based Organic Farming for mitigation of and adaption to Climate Change

The organic food and agriculture movement is gaining in strength in spite of the monumental opposition of agrochemical industries, whose economic existence depend on synthetic fertilizers and pesticides. The movement is gathering momentum in spite of the dominant view of the agriculture development as farmers are increasingly becoming aware that industrialized chemical farming entails an ever increasing production cost and rapidly declining soil fertility, crop yield and livelihood security.

Localized biodiverse ecological agriculture can reduce green house gas emission by significant amount while improving our natural capital of biodiversity, soil and water; strengthening natures economy; improving the security of farmers livelihoods; improving the quality and nutrition of our food (Shiva, 2008).

An analysis of energy in the US food chain found that on an average, it takes 10 calories of energy to produce one calorie of food. A shift to ecological,

### Agro-biodiversity, climate resilience and sustainability

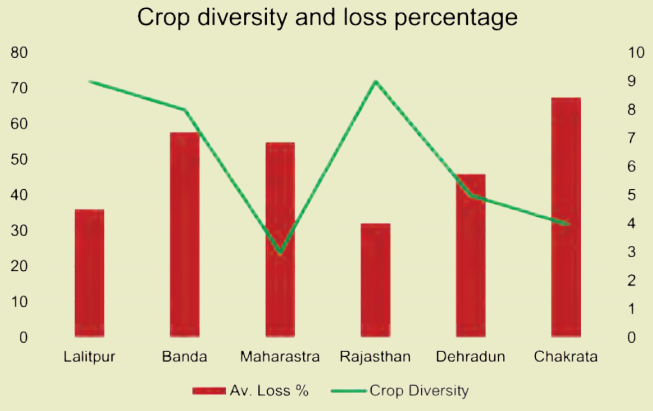
Recently Navdanya did a study on the impact of Crop diversity in food security and economic sustainability in 5 regions of Uttarakhand, 2 regions in Bundelkhand and one region each in Maharashtra, and Rajasthan.

In the study crop loss due to untimely rainfall occurred during crop ripening and harvesting period was observed. Results clearly reveal a positive correlation between decreasing agro-diversity and quantitative increase in crop loss. Increasing diversity within the species coupled with use of traditional open pollinated strains show increased food and economic security against climate change related crop damage.

As per Government reports over 2 million tons of pulse crop production is reduced due to changed weather condition during the rabi crop season.

In Rajasthan, Maharastra, Uttar Pradesh and Dehradun and chakrata area of Uttarakhand production of major wheat reduced by 30 to 70%. Within the wheat varieties wheat lokman (Lokone) in Lalitpur (Bundelkhand, U.P.) and wheat 306 in Rajasthan, affected marginally as both varieties are old selection varieties. In pulses only traditional variety of lentil called Teen Fool wali masoor could survive, whereas all other lentil varieties could not sustain in the changed weather conditions.

Higher diversity of crops in Rajasthan and lalitpur also showed correlation with less crop loss. While in Maharashtra, Banda and Chakrata area where diversity was less farmers suffered heavy crop loss.



non industrial agriculture from industrial agriculture leads to two to seven fold energy saving and a 5 to 15 percent global fossil fuel emissions offset through the sequestration of carbon in organically managed soil. Up to 4 tons of CO2 per hectare can be sequestered to organic soils each year (Shiva, 2008).

Experiments by marginal farmers in the global south as well as by scientists reveal that complete replacement of chemical fertilizers and chemical pesticides/herbicides with organic manure can improve soil fertility and have fewer detrimental effects on the environment without compromising crop yields. In contrary to the chemical fertilizer which are rapidly dissolved in water and its significant part is lost either by leaching or other means, organic fertilizers decomposes slowly hence releasing nutrients gradually. This process of slow nutrient release, contribute to accumulation of carbon and nitrogen and minimize leaching losses (Jenkinson, et al., 1994). Productivity of farms is stable in organic farms because nutrient cycling is made tighter in the agro-ecosystem by organic inputs than by synthetic chemical inputs "sustainable and productive ecosystem have tight internal cycling of nutrients a lesson that agriculture must relearn" (Tilman, 1998).

Results from experiments at the Rothamstead experimental station in UK shows that over 150 year soil organic matter and total nitrogen level increased by 120 % in manured plots compared with only about 20 % in the plots receiving chemical fertilizer inputs (Jenkinson, 1994, Powlson, 1994).

The Farming Systems Trial (FST) at Rodale Institute is America's longest running, side by-side comparison of organic and chemical agriculture. Started in 1981 to study what happens during the transition from chemical to organic agriculture, the FST surprised a food community that still scoffed at organic practices. After an initial decline in yields during the first few years of transition, the organic system soon rebounded to match or surpass the conventional system. Over time, FST became a comparison between the long term potential of the two systems.

Corn and soybean acreage comprised 49% of the total cropland in the U.S. in 2007. Other grains made up 21%, forages 22% and vegetables just 1.5%. Throughout its long history, the FST has contained three core farming systems, each of which features diverse management practices: a manure-based organic system, a legume-based organic system, and a synthetic input-based conventional system. In the past three years of the trial, genetically modified (GM) crops and no-till treatments were incorporated to better represent farming in America today. Results and comparisons are noted accordingly to reflect this shift.

As per Rodale Institutes studies, Organic yields not only matches the conventional yields but Organic outperforms conventional in years of drought. It also states that Organic farming systems build rather than deplete soil organic matter, making it a more sustainable system. Organic farming uses 45% less energy and is more efficient. Conventional systems produce 40% more greenhouse gases in comparison to Organic farming. It also confirms that Organic farming systems are more profitable than conventional farming systems.

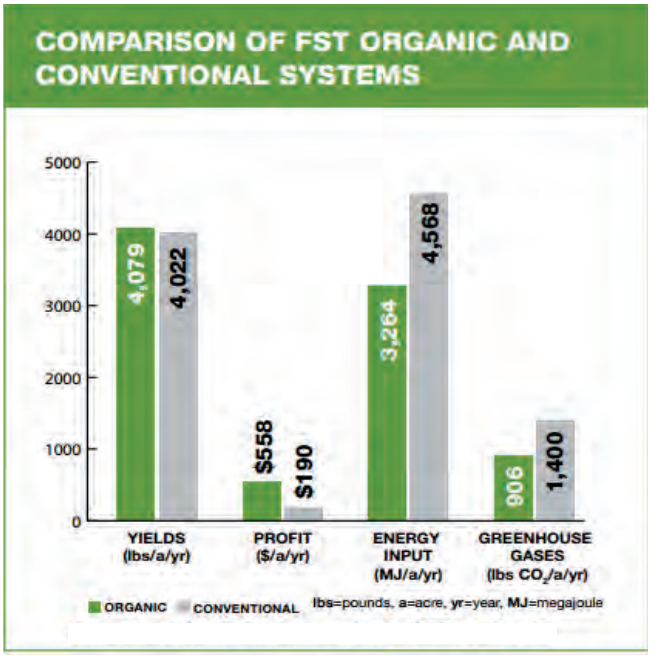



**Fig 6:** Source: http://rodaleinstitute.org/assets/FSTbooklet.pdf.

Navdanya for the last 3 decades has been practicing promoting and researching on agriculture that conserves biodiversity, strengthens farmers Seed Sovereignty and Food Sovereignty, increases nutrition per acre, thus addressing malnutrition and hunger and increases small farmer's income thus simultaneously addressing poverty and climate change.

A study conducted by Navdanya in four districts of West Bengal shows that multiple cropping in the same soil and climatic regimes prove economically more efficient than modern intensive chemical farming systems involving monocultures (Deb, 2004). The

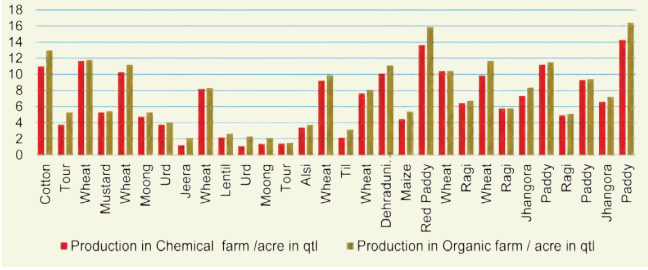
study further reveals that the relative value of the farm produce increases significantly with greater diversity of crops, whereas productivity rises even more when crop farming is integrated with animals.

The biodiversity based traditional farming systems are a result of years of intense selection based on prevalent agro-hydrological regimes inaccessibility of resources and ecological fragility. These factors culminated forward the genesis of subsistence production systems that were sustained with the organic matter and the nutrient derived from the forests (Maikhuri, *et al.*, 1997).

A study done by Navdanya in the Rabi season of the year 2014- 2015 and Kharif season of the year 2015 in 9 different regions of 5 states of India that includes Maharashtra, Odisha, U.P., Uttarakhand and Rajasthan clearly reveals that in climate stress conditions including drought or heavy rains organic farming is far better than the chemical farming. All the 9 regions are different from each other. Where Rajasthan is arid zone and Bundelkhand and Maharashtra are drought prone areas, whereas Odisha is flood prone area. Within Uttarakhand Dehradun is a valley at an altitude of about 500m amsl and Purola valley is situated at an altitude of 1500m amsl. Rudraprayag and Tehri are amongst the hill districts of the state.

Results are summarized in the table and bar diagram below which shows that crops grown in organic farms have performed better than that was grown in the chemical farms. This study is being done with 1074 farmers of above mentioned 5 states of India who shifted to organic in the year 2013 with the help of Navdanya. Range of crops includes Dehraduni Basmati, Red paddy, Wheat, Maize, Mustard, Tuor, Urad, Moong, Jeera, Lentil, Ragi Jhangora and Cotton.

Fig 7: Comparative Productivity analysis of Chemical vs. Organic farms in Rabi 2014 - 2015 and Kharif season 2015 under climate stress condition




Average percent increase varied from 0.85% to 106.25%. Everywhere organic farms performed better than chemical farms even in the climate stress condition which clearly confirms that organic farming is much better even in the climate stress conditions irrespective of the area or crop.

**Table 3: Showing Comparative Productivity analysis of Chemical vs. Organic farms in Rabi 2014 - 2015 and Kharif season 2015**

| SN. | Area | Crops | Production in Chemical farm /acre in qtl | Production in Organic farm/ acre in qtl | Average Increase (%) in Organic farm |
|---|---|---|---|---|---|
| 1 | Amravati, Maharashtra | Cotton | 11 | 13 | 18.18 |
| | | Tour | 3.8 | 5.3 | 39.47 |
| | | Wheat | 11.7 | 11.8 | 0.85 |
| 2 | Tonk, Rajasthan | Mustard | 5.3 | 5.43 | 2.45 |
| | | Wheat | 10.3 | 11.2 | 8.74 |
| | | Moong | 4.8 | 5.3 | 10.42 |
| | | Urd | 3.8 | 4.1 | 7.89 |
| | | Jeera | 1.23 | 2.1 | 70.73 |
| 3 | Lalitpur, Uttar Pradesh | Wheat | 8.2 | 8.3 | 1.22 |
| | | Lentil | 2.2 | 2.67 | 21.36 |
| | | Urd | 1.12 | 2.31 | 106.25 |
| | | Moong | 1.43 | 2.11 | 47.55 |
| 4 | Banda, Uttar Pradesh | Tour | 1.45 | 1.55 | 6.90 |

| | | | | | |
|---|---|---|---|---|---|
| | | Alsi | 3.44 | 3.76 | 9.30 |
| | | Wheat | 9.22 | 9.88 | 7.16 |
| | | Til | 2.15 | 3.22 | 49.77 |
| 5 | Dehradun, Uttarakhand | Wheat | 7.66 | 8.11 | 5.87 |
| | | Deh-raduni Basmati | 10.11 | 11.13 | 10.09 |
| | | Maize | 4.5 | 5.4 | 20.00 |
| 7 | Purola, Uttarakhand | Red Pad-dy | 13.65 | 15.87 | 16.26 |
| | | Wheat | 10.43 | 10.44 | 0.10 |
| | | Ragi | 6.44 | 6.74 | 4.66 |
| 8 | Tehri, Uttarakhand | Wheat | 9.88 | 11.68 | 18.22 |
| | | Ragi | 5.77 | 5.78 | 0.17 |
| | | Jhangora | 7.33 | 8.37 | 14.19 |
| | | Paddy | 11.23 | 11.55 | 2.85 |
| 9 | Rudraprayag, Uttarakhand | Ragi | 4.99 | 5.11 | 2.40 |
| | | Paddy | 9.32 | 9.42 | 1.07 |
| | | Jhangora | 6.59 | 7.23 | 9.71 |
| 6 | Balasore, Odisha | Paddy | 14.32 | 16.43 | 14.73 |

## Agro-ecology and climate change

Climate adaptability and feeding nine billion are two major challenges of the day which can be met easily adopting the Agroecological approach and promoting and empowering the family farms. Family farms are the custodians of agroecological approach, that can play a crucial role in meeting the needs of a still growing global population, as agroecology offers the prospect of sustainable food production.

Agroecolgical farming also helps reducing the GHG emissions from the agricultural sector and building resilience to already unavoidable changing climate through protecting biodiversity for sustaining communities and rural livelihoods.

## Principles of agroecology

Principles of agroecology revolve round an agroecosystem – community of plants, animals and microorganisms, the three functional biotic components, interacting with each other and among themselves and with the physico-chemical environment modified by farmers to produce foods, fodder, fiber, fuel, and other useful products. Agroecology provides us an opportunity to make a holistic understanding of the agroecosystems which we design and manage for food production.

Agroecological principles laid down by Reijntjes et al. (1992) and intensively discussed by Altieri (1987, 2000) and Singh (2005) are:

- Enhancing recycling of biomass and optimizing nutrient availability a nd balancing nutrient flow;
- Securing favourable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity;
- Minimizing losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover;
- Species and genetic diversification of the agroeco-system in time and space; and
- Enhancing beneficial biological interactions and

synergism among agrobiodiversity components thus resulting in the promotion of key ecological processes and services.

Since ages farmers had been protecting, conserving and augmenting natural resources, such as forests, grasslands, biodiversity in forests / agro-biodiversity, livestock, soil, water resources, and overall farming cultures through applying the principles of agroecology.

Agroecology helps us understand and maintain vital mineral cycles, biological processes, energy transformations, and socioeconomic relationships in an integrated manner. Agricultural strategies woven around the principles of agroecology look into local geographical and socioeconomic specificities, environmental and cultural specificities, and obeys people's traditions, such as food habits, festivities and their ethical and aesthetic values (Singh et al 2014).

Some of the strategies for diversification of agro-ecosystem are:

- **Agroforestry Systems:** Trees or other woody perennials, annual crops and livestock are integrated to enhance complementary relations between components increasing multiple use of the agroecosystems.

- **Mixed farming / Polycultures:** Two or more crop species are planted together, for example shallow-rooted millets with deep-rooted pulses, so that more yield of more than one food/ economic products is taken per unit area.
- **Cover Crop:** Pure or mixed stands of legumes or other annuals under fruit trees for improving soil fertility, for biological control of pests, and for modifying microclimate.

- **Crop Rotations:** Sequential diversity in cropping systems, providing nutrients and breaking life-cycles of several insect-pests, diseases and of weeds.

- **Livestock:** animals are integral part of any agro-ecosystem. Livestock help create extra nutrient and energy pathways to enable produce a variety of foods, draught power, hauling cart, and enhancing nutrient recycling.

## Agroecology, traditional farming systems and climate adaptation

Traditional farming systems throughout the world are rich in agro-biodiversity. Such systems in which both biodiversity and ethno-diversity are rich are still alive in the mountainous or uneven terrain, where communities are marginalized by socio-economic and/or bio-physical conditions.

These mountain systems exhibit remarkable landscape mosaics, ingenious resource management and recycling techniques, intricate conservation measures for intra and inter-specific variability, and ecosystem resilience and robustness that enable traditional communities cope with unexpected environmental and so-

cio-economic changes and alleviate risk. They, in turn, reinforce traditional knowledge and customs that make these communities cohesive and somewhat self-reliant.

These farming systems and the agro-biodiversity conserved in such places are threatened by economic globalization and global climate change through a range of locally variable factors, such as the penetration of global consumer media in remote markets, agricultural intensification for commodity markets through price subsidies, chemical inputs and/or high-yielding exotic crop varieties (including genetically modified organisms), policy and market distortions primarily through high agricultural subsidies in the industrialized countries. The low prices paid for agricultural commodities, neglect in R&D and knowledge generation for sustainable rural development linked to urban markets it is a threat to under developed / developing countries. These threats induce traditional knowledge and cultural erosion, natural resource overuse and degradation, productivity declines, agro-biodiversity loss and the substitution with exotic varieties, and/or distinct changes in agro-ecological zones, resulting in food insecurity, unsustainable livelihoods and urban migration.

Today there is an urgent need to understand the nature of traditional knowledge and socio-cultural and economic factors that enable remote traditional societies harness agro-biodiversity and natural resources to promote ecosystem resilience and robustness that alleviates risk and provides the key ingredients for adaptation to unexpected disasters, since they have a bearing on climate adaptation.

Traditional farmers manage the soil in such a way that it should continue to be replenished by nutrients through manure, recycling, in-situ fertilization, mixed cropping, mulching and other management practices. They still adhere to an old adage – don't feed the plant, feed the soil which feeds the plant.

Farmers cultivate as much agro-biodiversity as could be possible in a particular area. They also manage the natural biodiversity in uncultivated areas (forests, grasslands, rangelands, etc.). This biodiversity is a key to sustainability. Higher the degree of biodiversity, higher the level of sustainability. Farmers also manage cyclic flows of nutrients. Whatever nutrients are extracted from croplands are recycled into the same soil through manure. The soil fertility is further enhanced by supplementing the nutrients from forest soil.

This wonderful practice of traditional farming is an example of the living carbon cycle that maintains and regenerates living soil (figure 8).

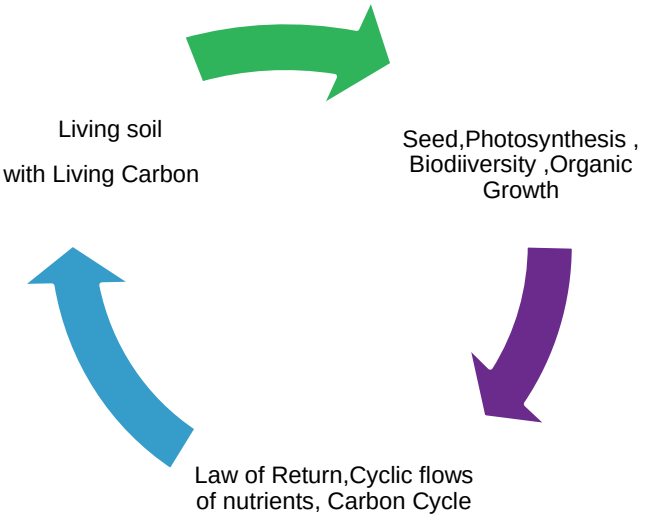



**Fig. 8:** Cycle of sustainability

## Organic farming, water conservation and draught insurance

Water is a limiting factor in dry lands, and changes in water availability can have disproportionate effects on biodiversity. Hence, balancing human and wildlife needs for fresh water is essential to dry and sub-humid lands adaptation to climate change. This can be achieved through sustainable and efficient management of water resources. Another adaptation strategy consists of restoring degraded lands.

Further, Climate Change is leading to more extended and more frequent draughts. Besides contributing to mitigation of Climate Change, by increasing organic matter in the soil, agroecology and organic farming also increases soil moisture conservation and draught resilience.

## Organic soils: A water reservoir

Researches in different parts of the world show that organic farming systems use water more efficiently due to better soil structure and higher levels of humus and other organic matter compounds. D.W. Lotter and colleagues collected data over 10 years during the Rodale Farm Systems Trial. Their research showed that the organic manure system and organic legume system (LEG) treatments improve the soils' water-holding capacity; infiltration rate and water capture efficiency.

The LEG maize soils averaged 13 percent higher water content than conventional system (CNV) soils at the same crop stage and 7 percent higher than CNV soils in soybean plots. The more porous structure of organically treated soil allows rainwater to quickly penetrate the soil, resulting in less water loss from runoff and higher levels of water capture. This was particularly evident during the two days of torrential downpours from hurricane Floyd in September 1999, when the organic systems captured around double the water as the conventional systems. Long-term scientific trials conducted by the Research Institute of Organic Agriculture in Switzerland comparing organic, biodynamic and conventional systems had similar results showing that organic systems were more resistant to erosion and better at capturing water.

Following table shows the huge potential of organic matter not only in retaining the rain water but also reducing the soil erosion which has expedited by the extensive use of chemicals in agriculture worldwide.

**Table 4:**

| Volume of Water Retained /ha (to 30 cm) in relation to soil organic matter (SOM) | |
|---|---|
| • 0.5% SOM | 80,000 litres (common level Africa, Asia) |
| • 1% SOM | 160,000 litres (common level Africa, Asia) |
| • 2% SOM | 320,000 litres |
| • 3% SOM | 480,000 litres |
| • 4% SOM | 640,000 litres (levels pre farming) |
| • 5% SOM | 800,000 litres (levels pre farming) |
| • 6% SOM | 960,000 litres (levels pre farming) |

(Adapted from Morris, 2004).

# The Raging Elephant in the Climate Change Room

More than **50%** GHG emissions are related to industrial agricultural production, most of which is methane from animal husbandry and **nitrous oxide** from chemical fertiliser use.

**Ecological Agriculture - The Only Solution**

We need to reduce stocks of atmospheric Carbon and return it to the soil - where it belongs. The only way to put $CO_2$ back in the soil is by working with biodiversity, farmers' seeds in farmers' hands, and ecological organic farming practices, away from fossil fuels and their derived chemicals. Adapting to climate change is only possible working *with nature.*

It takes the **energy-equivalent of 2 litres** of **diesel** to make **1 kg** of synthetic nitrogen fertiliser

**$N_2O$** has roughly **300 times** the **Global Warming Potential** of $CO_2$ while **Methane** has roughly **20 times. Industrial Agriculture** is responsible for **67% of the $N_2O$** in the atmosphere.
(IPCC - Fourth Assessment Report)

**48%** of **$CH_4$** emissions and **52%** of **$N_2O$** emissions come from **Industrial Agriculture**

Organic farms sequester **550 Kgs Carbon per hectare per year -** 2018.5 Kgs $CO_2$ per hectare per year. **Adoption** of current **organic practices globally** has the **potential** to sequester around **10 Gigatonnes** of **$CO_2$ by 2020.**

*Fossil* Revolution **Borlaug's** dwarf varieties, **bred for chemicals** and grown as monocultures, produce **less nutrition and sequester less carbon per acre while increasing emissions.**

By promoting **#FossilAgriculture** and #BioPiracy **Bill Gates** is the single **most powerful driver** of the **Climate Crisis** and **major force** in the **destruction** of **small scale ecological agriculture** - the **SOLUTION.**

We can **meet** the **2-degree** emissions gap **by 2020** if we **switch** globally from fossil fuel intensive **industrial** #fossilagriculture to **organic**

## False Solutions

Based mostly on an Ecomodernist approach, these false solutions reflect an ignorance of how we depend on nature for the very air we breathe.

**#1 Climate Smart Agriculture (CSA) is an extension of the fossil fuel** intensive industrial model of **agriculture** - directly responsible for more than half the climate crisis. Industrial varieties, even hybrids, require chemical fertiliser use. #fossilAgriculture

**#2 GMOs and Biopiracy** Climate resilience cannot be engineered into GMOs. GMOs are based on the biopiracy of farmers varieties. **Syngenta** attempted to pirate **22,972 Indian** rice varieties. in 2004, **Monsanto's** biopiracy patent on **Indian Wheat,** of Indian Melon, Brinjal and even the gene for it's patented **BT technology.** The **5 Gene Giants** have **1,500 Biopiracy based patents** on **climate resilient crops**

**#3 GeoEngineering** could quadruple atmospheric carbon dioxide levels
**levelshttp://www.wired.com/2012/07/geoengineering-climate-change/**

**#4 Carbon Trade** destroying the living carbon in soils worldwide by using nitrogen fertilisers and other chemicals, and then trading it will make soil and climate data another commodity farmers must buy from corporations like **Monsanto**

**#5 Carbon reductionism** falsely equating living carbon - which is life and which must grow - with dead fossilised carbon - which must be kept underground!

**Green Carbon** (Organic matter) is **not substantially equivalent** to **fossilised carbon.**

**#FossilAg**

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# 4

# Biodiversity: A Climate Solution

Biodiversity is our only insurance against Climate Change. Diversity offers a cushion against both climate extremes and climate uncertainty. Biodiversity increases resilience to climate change by returning more carbon to the soil, improving the soil's ability to withstand drought, floods, and erosion.

Diversity of living systems are an expression of their capacity to evolve and adapt. That is why scientists like Salvatore Cecarelli are increasingly focusing on agrobiodiversity conservation and evolutionary breeding. Agro-biodiversity in natural ecosystems has been adapting naturally or autonomously to changing conditions. As the magnitude of climate change increases with time, the need for co evolution for adaptation becomes more acute. Traditionally, communities who depend on biodiversity resources have informal institutions and customary regulations in place to ensure that external perturbations do not exceed natural resilience beyond certain thresholds. *Van Panchayat* is one of such examples, which still exist in several parts of our country.

Keeping in mind the rate of changes taking place in the demographic, economic and socio-political landscapes of human society and their positive feed-back to the climate system, the time tested, age-old approaches may need to be supplemented by present day formal adaptation measures to address the new threats to biodiversity.

The *in situ* and *ex situ* conservation of crop and livestock genetic resources is important for maintaining options for future agriculture needs. *In situ* conservation of agricultural biodiversity is defined as the management of a diverse set of crop populations by the farmers in the ecosystem where the crop evolved. It allows the maintenance of the processes of evolution and adaptation of crops to their environment. *Ex situ* conservation involves the conservation of species outside their natural habitat, such as in seed banks and greenhouses.

The conservation of the components of agricultural ecosystems that provide goods and services, such as natural pest control, pollination, and seed dispersal, should also be promoted. Indeed, 35% of the world's crop production is dependent on pollinators such as bees, birds and bats.

Biodiversity increases genetic diversity, which is indispensable to cope with environmental stresses and is the cornerstone of small farmers' livelihood strategies. It is also the basis for food security as it provides alternatives to fossil fuels and chemical inputs for small scale and ecological farms. Biodiversity is the only ecological insurance for society's future adaptation and evolution in the face of extreme weather patterns. Increasing genetic and cultural diversity in food systems and maintaining this biodiversity in the commons are vital adaptation strategies to respond to the challenges of climate change.

Monocultures, centralization and techno-fixes represent a myopic obsession that must give way to diversity and decentralization. Biodiversity and small-scale farms go hand in hand, yet corporate driven globalization policies that promote monocultures are pushing farmers off the land; policies that protect and expand biodiversity must be encouraged to mitigate the impact of climate change.

The resilience of ecosystems can be enhanced and the risk of damage to human and natural ecosystems could be reduced through the adoption of biodiversity-based adaptive and mitigation strategies. Mitigation is described as a human intervention to reduce greenhouse gas sources or enhance carbon sequestration, while adaptation to climate change refers to adjustments in natural or human systems in response to climatic

stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Examples of activities that promote mitigation of or adaptation to climate change include:

- Maintaining and restoring native ecosystems;
- Protecting and enhancing ecosystem services;
- Managing habitats for endangered species;
- Creating buffer zones;
- Conservation of local flora and fauna including agricultural crops and their landraces;
- Promotion of biodiversity based ecological farming and
- Documentation of indigenous knowledge.

## The wealth of biodiversity

Communities all around the globe derive many essential goods and services from natural ecosystems such as food, fresh water, timber, fuel wood, fiber, non-timber products, genetic materials, etc. Human economy clearly depends upon the services by ecosystems, carried out "for free". Natural ecosystems also perform fundamental life support services without which human civilizations would cease to thrive.

Since the beginning of life on the earth human beings developed knowledge and found ways to derive livelihoods from the bounties of nature's diversity, in wild as well as in domesticated forms. It is evident that a certain level of biodiversity is necessary to provide the material basis for human life: at one level to maintain the biosphere as a functioning system and, at another, to provide the basic materials for agriculture and other utilitarian needs.

Hunters and gathers in the beginning of civilization used thousands of plants and animals for their food, medicine, shelter and clothing, this number is coming down to limited number with the so called development. People are now dependent on very few plants for their livelihood, which created imbalance in the nature by promoting monocultures as well as by overexploitation of certain resources and indirectly imposing pressure on earth to fulfil the greed of humans.

Diversity is the characteristic of the nature and the basis of ecological stability. It is also a concept, which refers to the range of variation or differences among some set of entities. Biodiversity simply means the biological diversity, which refers to variety within the living world. The term is used commonly to describe the number, variety or variability of living organisms. In simple words, entire variety of plants animals and all other living organisms on the earth constitutes the biodiversity of our planet.

Biodiversity is not merely the genetic components of diverse species but the inter-relationships among the flora, fauna including microorganisms, soil, water, ecosystems or environment and cosmos as a whole.

The diverse climatic and ecological zones of our country provide a congenial setting for the evolution of a wide range of ecosystems. From the tropical Western Ghats to the temperate Himalaya and from the fertile coastal regions to the cold deserts of Ladakh, India supports a strikingly diverse and rich range of biodiversity.

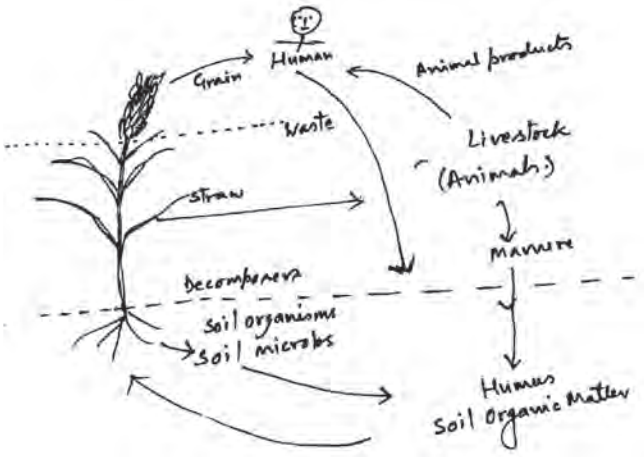
Many of the human activities that modify or destroy natural ecosystems may cause deterioration of ecological services whose value, in the long term, dwarfs the short-term economic benefits society gains from those activities. Fortunately, the functioning of many ecosystems could be restored if appropriate actions were taken in time. Climate change, including variability and extremes continue to impact on ecosystems sometimes beneficially, but frequently effects adversely on its structure and functions.

## Erosion of agro-biodiversity

Green Revolution farming practices involving homogenization of the crop genetic base has eroded biodiversity in agro-ecosystems including plant genetic resources, livestock, beneficial insects and soil organisms. Further, replacing indigenous varieties with high biomass, therefore high organic matter and a bigger contribution to the living carbon cycle with dwarf varieties adapted to chemical fertilisers disrupted both the carbon and nitrogen cycle.

Indigenous crop varieties were most suited to providing ecological functions and services, providing for human and animal needs. Grain was eaten by people, long straw was fed to cattle and cattle in turn enriched the soil with their dung. This dung was food for microorganism who in turn provided food for the crop. This cycle was completely broken during the last 60 years by the Green Revolution based on chemical monocultures of dwarf varieties, thus reducing food for

animals and for the soil (Vandana Shiva, The Violence of the Green Revolution).




Synthetic pesticide caused decline of both species diversity and abundance of spiders, bees, wasps, beetles, crickets, dragon flies and damselflies and earthworms alongside the buildup of resistance to pesticides in crop pests and pathogens of non target organisms has been a major cause of agro-ecological concern. Rachel Carson's (1961) classic 'Silent Spring' on the effect of DDT causing egg shell thinning of birds triggered a series of studies that have documented the role of pesticides in erosion of biodiversity.

Indigenous crop varieties can withstand a wide range of climatic and soil conditions, modern crop varieties tend to perish at small environmental variations like too early or too late rains. Crop landraces grown by traditional farmers continue to evolve genetically in response to human management and environmental changes. A large array of genes responsible for resistance to different pests, pathogens and environmental conditions are found in folk crop cultivars and their wild relatives. With the disappearance of folk varieties, the very genetic base for crop breeding and improvement is irretrievably lost. Fearing the loss of valuable genes, conservationists have launched efforts to collect and save folk crop seed samples for future use in ex situ gene banks (Jackson, 1995).

The Green revolution has led to high external input based intensive agricultural systems from the traditional self reliant agricultural system. About 7,000 plant species have been cultivated for food since agriculture was practiced by human beings. Today, however, only about 15 plant species and eight animal species supply 90% of our food. Many traits incorporated into these modern crop varieties were introduced from wild relatives, improving their productivity and tolerance to pests, disease and difficult growing conditions. Wild relatives of food crops are considered an insurance policy for the future, as they can be used to breed new varieties that can cope with the changing conditions.

Agricultural modernization has eroded the genetic base of most cultivated crops –rice, wheat, maize, potato through replacement with a handful of modern varieties (Fujisaka, 1999). Many wild races of staple food crops are endangered. For example, one quarter of all wild potato species are predicted to die out within 50 years, which could make it difficult for future plant breeders to ensure that commercial varieties can cope with a changing climate.

It is estimated that approximately 200,000 (2 lac) varieties of rice existed in India spread over 41 million hectares and producing 60 million tones of rice annually. It has now being demonstrated and proved that narrow genetic base in rice in India is a result of strategy of introduction of HYV containing dwarfing gene from Taichung I and IR 8. (Richharia and Govindswami,1990).

## Climate change: An anthropogenic threat to biodiversity

Biodiversity is immensely threatened by the climate change, but proper management of biodiversity can reduce the impacts of climate change. There are large numbers of scientific evidences which prove that the climate change is already affecting biodiversity and will continue to do so. The Millennium Ecosystem Assessment ranks climate change among the main direct drivers affecting ecosystems.

Major consequences of climate change on the species biodiversity include:

- Changes in distribution pattern of the species;
- Increased vulnerability and extinction rates;
- Changes in reproduction timings, and
- Changes in growing seasons for plants.

Some species that are already threatened are particularly vulnerable to the impacts of climate change (WWF online report). The recently extinct golden

toad and *Monteverde harlequin* frog have already been labeled as the first victims of climate change (Pounds, 1999).

Since frogs rely on water to breed, any reduction or change in rainfall could reduce frog reproduction. Moreover, rising temperatures are closely linked to outbreaks of a fungal disease that contributes to the decline of amphibian populations. The projected rise in sea levels could cause the disappearance of the tigers' habitat in the mangrove forests of Asia.

## Biodiverse farming system a natural insurance against climate change

Diversity of crops in any given farm is a real insurance in times of climate change. Traditionally, farmers have increased their resilience by growing more than one crop.

At Navdanya's biodiversity farm in Doon valley (Uttarakhand), we have build on this ancient time tested knowledge, farming in natures' ways, based on biodiversity. At farm while experimenting with the mixed cropping system in several combinations of seven, nine and twelve crops (*baranaja*), verses monocultures, we found that mixed biodiverse crops always performed 2-3 times better than that of monocultures. They are also capable of tolerating the frost, drought, early, late or even very little rains (Shiva, 2008).

## Navdanya's 3 steps for enhancing climate resilience in agriculture

Multifunctional, biodiverse farming systems and localized diversified food systems are essential for ensuring food security in an era of climate change. A rapid global transition to such systems is an imperative both for mitigating climate change and for ensuring food security. This report is a demonstration of our firm commitment to our belief that we will endure climate chaos only by ensuring that biodiversity and its nurturing conditions flourish and that climate resilience and climate-adapting strategies remain in the commons, not in corporate hands. Farmers' Breeding and Nature's Evolution Maintains Biodiversity Genetic diversity and farmer's breeding has enabled agriculture to respond to changes over the past 10,000 years, and it is precisely this diversity that will play a key role in adapting agriculture to climate change in the decades ahead. Industrial mechanistic and reductionist solutions replace intimate knowledge of biodiversity and ecosystems with careless technologies. Use of agrichemicals and genetic engineering destroys and depletes the very biodiversity, soil, air and water that agriculture depends upon while simultaneously further destabilizing the climate. The two most important resources for adapting agriculture to local climate change conditions are the genetic diversity of plants and the diverse knowledge and practices of farming communities.

Crop genetic diversity plays a key role in coping with environmental stresses, and traditional and indigenous knowledge systems incorporate essential principles of adaptation, diversity and plurality. The diversity of cultures and of knowledge systems required for adapting to climate change need recognition and enhancement through public policy and investment.

Challenging false solutions resisting the biopiracy of climate resilient crops evolved by farmers In the face of a swelling food crisis and climate chaos, the corporate led "climate-resilient" gene campaign is a distracting and deceptive public relations push of seed companies who attempt to represent themselves as climate saviors while obscuring root causes of climate change and real solutions. Patented techno-fix seeds will not allow the adaptation strategies that small farmers, especially the most vulnerable poor farmers, need to cope with climate change. These proprietary technologies will ultimately concentrate corporate power, drive up costs, inhibit independent research, and further undermine the rights of farmers to save and exchange seeds. These patented solutions represent a violation of farmers' knowledge, a commons accessible to all, and people's rights to be able to develop climate adapting strategies.

# 5

# Seeds of Hope, Seeds of Resilience: How Biodiversity makes Agriculture and Communities more Resilient to Climate Change

There are 4 ways in which Biodiversity and Seed Freedom creates climate resilience and is a climate solution

1. Firstly farmers have bred Climate Resilient Seeds and varieties that are contributing to resilience
2. Secondly, Diversity of crops increases the resilience of farming to climate change. If you have only one crop in a monoculture, it is more vulnerable to changing climate. Farmers growing monocultures of commodity crops are also more vulnerable to exploitative markets.
3. Thirdly, biodiversity intensification allows more carbon to be absorbed from the air, returned to the soil, thus decreasing excess carbon in the atmosphere while also increasing the resilience of soils to draught, floods and climate change.
4. Fourthly, when farmers have their own renewable, regenerative seed, they can replant after a climate disaster, which contributes to both climate resilience and economic resilience. If farmers are dependent on purchase of costly non renewable seeds from corporations, not only do they loose their crop, they loose their sovereignty and have to get into debt. Debt is the single biggest reason for the more than 300,000 farmers suicides in India since 1995.

## Farmers innovation and climate resilient Seeds: Climate change requires farmers' breeding and local adaptive strategies

Plant breeding plays an essential role in adapting agriculture to rapidly changing climates. Even when formal sector scientists use the most sophisticated climate models and the most advanced technologies, the reality is that they are not very good at predicting what happens at a very local level and on the ground realities. While genetic uniformity is the hallmark of commercial plant breeding, farmer-breeders, rooted in local level realities, deliberately create and maintain more heterogeneous varieties in order to withstand diverse and adverse agroecological conditions. The crop diversity developed and maintained by farming communities already plays a role in adapting agriculture to climate change and variability. Additionally, farmers adapt quickly to changing climates by shifting planting dates, choosing varieties with different growth duration, changing crop rotations, diversifying crops, and using new irrigation systems among other strategies. Farmer-led strategies for climate change survival and adaptation must be recognized, strengthened and protected. Farming communities must be directly involved in setting priorities and strategies for adaptation.

Farmers' knowledge and technology have never been stagnant or static. They have always skillfully responded to the changing circumstances and have kept their system in a dynamic state advancing towards higher degree of diversity, complexity, resilience, sustainability, and security. In the process of achieving these goals, farmers have always based their livelihood systems on natural biodiversity. They unabatedly searched, selected, cultivated, bred, preserved, protected, saved, conserved, experimented with, managed, used, enriched, shared, distributed, and disseminated the germplasm, which is the living testimony of their innovations. Not only this, they also dutifully passed this germplasm on to the next generations.

Systematic modern agricultural experiments are just about half century old, whereas farmers' experiences are millennia old. They cannot be ignored or rejected as mere remnant of the past. Farmers' knowledge and technology are futuristic and innovative and are governed by ecological laws. They must find central place in our contemporary agricultural strategies. Recent advances in technology will be welcome provided they have compatibility with those evolved by farmers and are rooted in local realities (Singh *et.al* 2013).

While highly expensive High yielding seeds, hybrid seeds and GMO's continue to fail, indigenous open pollinated climate resilient varieties are proving to be an important option for adaptation to climate change. Evidence from farmers fields prove that indigenous crop varieties can withstand a wide range of climatic and soil conditions, whereas "modern" crop varieties tend to perish at small environmental variations like rains arriving too early or too. Farmers varieties grown by traditional farmers continue to evolve to adapt to changing environmental conditions. With the disappearance of biodiversity due to industrial monocultures, the very genetic base for crop breeding for climate resilience is being irretrievably lost. Fearing the loss of valuable genes, conservationists have launched efforts to collect and save folk crop seed samples for future use in ex situ gene banks (Jackson, 1995).

Navdanya's experience of working with farmers across the county reveals that climate resilient seeds with organic farming are better than "high yielding" seeds in chemical farming. Recent study done by Navdanya in Odisha, Bundelkhand, Uttarakhand and Maharashtra confirms that open pollinated Indigenous seeds are better alternatives to the hybrid, high yielding or GM seeds. Hundreds of farmers in Odisha those who were given indigenous seeds by Navdanya after the Phailin super cyclone, got very good yields.

As an insurance against such vulnerability Navdanya has pioneered the conservation of biodiversity in India and built a movement for the protection of small farmers through promotion of ecological farming and fair trade to ensure the healthy, diverse and safe food. Navdanya's program for promoting ecological agriculture is based on biodiversity, for economic and food security. Today as a result of Navdanya's pioneering work many small groups and entrepreneurs have entered in the field of biodiversity conservation, organic farming and marketing of organic food products.

Navdanya's experience of working with farmers across the country and Bhutan established that through adopting the principles of agroecology and biodiversity based organic farming farmers could not only increase their yields by 2 to 3 times but vis-à-vis can reduce their input costs. Indigenous open pollinated varieties are not only capable of producing more but are also resilient to the climate. Comparative studies of 22 rice-growing systems have shown that indigenous systems are more efficient in terms of yields, and in terms of labour use and energy use (Shiva & Pandey 2006).

Researchers' world over has already proven the importance of indigenous crops and organic farming practices in coping with the changing climatic conditions. Results of our studies in the past in different agro climatic situations confirms that even in the adverse climatic conditions biodiversity based organic farming (higher crop diversity) is better capable to minimize the crop losses than that of monoculture based industrial farming.

Climate resilient traits will become increasingly important in times of climate instability. Along coastal areas, farmers have evolved flood tolerant and salt tolerant varieties of rice such as "Bhundi", "Kalambank", "Lunabakada", "Sankarchin", "Nalidhulia", "Ravana", "Seulapuni", "Dhosarakhuda".

Crops, such as millets, have been evolved for drought tolerance, and provide food security in water scare regions, and water scarce years. Corporations like Monsanto have take 1500 patents on Climate Resilient crops. Navdanya/Research Foundation for Science, Technology and Ecology, have published the list in its report, "Biopiracy of Climate Resilient Crops: Gene Giants Steal Farmers Innovation".

Navdanya decided to save these vanishing rice diversities of Odisha through a system of germ-plasm -conservation employing both in situ and ex situ methods and at the same time carry out experiments on their sustainability in varied eco-climatic conditions in view of rapid climate change and yield potentials under various soil amendments. Their behaviours and responses are being recorded. This came handy while selecting the seeds of specific rice diversities for empowering the local communities in rehabilitating agriculture in disaster areas like Erasama in Odisha after the Orissa super cyclone in 2000, Nagapattinam in Tamilnadu after the boxing day tsunami in 2005 and Nandigram in Bengal in 2007.

Navdanya has also given hope to the victims of tsunami. The tsunami waves affected the agricultural lands of the farmers due to intrusion of seawater and deposition of sea land. More than 5203.73 hectare of agricultural land in Nagapattinam was affected by the tsunami. The Navdanya team conducted a study in the affected villages to facilitate the agriculture recovery. The team, distributed 3 saline resistant varieties of paddy, which included Bhundi, Kalambank and Lunabakada, to the farmers of the worse affected areas. These varieties of native saline resistant kharif paddy seeds were collected from Navdanya farmers in Orissa amounting to a total of 100 quintals.

Navdanya Odisha as of now maintains 4 seed banks, 3 village level and 1 central level, where seeds of diverse rice varieties are conserved and renewed every year. Climate resilience factor is given importance in the village level seed banks when all available rice land races are conserved in the central seed bank. Navdanya also encourages individual cultivators to save, exchange and increase diversities in his/ her own fields. The village level seed banks are located in different and varied eco-climatic zones, like salt prone, flood prone and drought prone areas. The central seed bank has 810 rice varieties in its accession out of which 119 varieties are climate resilient. 33 of these are salt and flood tolerant including 1 aromatic variety, 47 are flood tolerant and 39 are drought tolerant including 3 aromatic and 2 therapeutic rice varieties. The rest 581 varieties belong to the general category. There are 56 aromatic rice varieties of which 2 have unique and diverse aroma, 1 smelling like fried green gram and the other, like cumin seed not available anywhere in the world. The therapeutic rices are used in old age tissue rejuvenation.

Seed exchange has been the back bone of paddy cultivation until the green revolution. Native paddy plants have diverse basal sheath colours, with about 9 shades of 5 colours, ranging from green, yellow, purple, violet to black. Reappearance of wild variety is an inherent character of paddy cultivation. Cultivators, hence, replace the variety with a different basal sheath colour next season just to be able to distinguish the weeds which are then manually removed. All the green revolution varieties have the same basal sheath colour, making it difficult to distinguish the wild weed which is never removed. A particular variety cultivated in a given field for more than 3 years lose yield, hence, is replaced. This replacement used to be procured through seed exchange, a part of the barter system that was in place till a few decades ago. Thus the cultivators used to gain twice, a new variety and an ensured more yield as the new variety always yielded more. The green revolution proponents do not contribute to this gospel truth. It has been further found out that seeds exchanged over a long distance for growing in the same type of micro-climate not only yielded much more but often even changed its potentials.

Two examples will suffice to put all doubts at rest.

Udasiali, an indigenous photosensitive kharif paddy variety transported over 500 kilometers from Balasore to Erasama in Jagatsingpur as part of post 1999 super cyclone disaster agricultural rehabilitation yielded at par in rabi.

Three select Odisha salt tolerant paddy varieties transported over a distance of over 1500 kilometers from Balasore to Nagapattinam in Tamilnadu under the 'seeds of hope' programme following 2004 tsunami yielded three times more and far better than any known high yielders. The same varieties behaved even better when cultivated in Indonesia, another 1000 or more kilometers away, in 2006 by Professor Friedhelm Goltenboth of Hohenheim University, Germany.

## Climate resilient seeds to cope with climate change

With the increasing events of disasters, we started conserving climate resilient seeds. We also encouraged farmers to grow and multiply native climate resilient varieties and started a program "Seeds of Hope" to help the disaster affected farmers with the climate resilient seeds.

It is predicted that 4°C increase in temperature due to climate change will reduce rice yield by 10%. Rice has been found to be quite climate resilient. Rice as a crop originally flourished in the dry climate of central Asia, and later spread to the wet tropical Asia, thus evolved the low land rice varieties with better yield.

Odisha is very well known for its rice diversity; therefore Odisha was selected for the conservation and multiplication of climate resilient paddy and vegetable seeds. Climate resilient varieties conserved by Navdanya in Odisha are given below:

## Salt tolerant varieties

Navdanya has conserved 33 salt tolerant varieties. Odisha salt tolerant rice land races have caused miracle both in Nagapattinam and Indonesia (post tsunami) where some of them such as Lunabakada, Kalambank, Bhundi, and Dhala sola have on an average produced 35-54 tillers in the SRI method.

## Flood tolerant varieties

In last 20 years Navdanya has conserved 54 flood tolerant varieties in Odisha. Of these 8 varieties are extremely water tolerant. These varieties are being conserved and multiplied at Navdanya's biodiversity conservation farm and Seed Bank in village Chandipur, Balasore as well as by the Navdanya member farmers in Odisha.

## Drought tolerant varieties

It is one of most serious worldwide problems for agriculture owing to very less rainfall. About 4/10th of the World's agricultural land lies in arid and semiarid regions, where less water demanding crops like millets, pulses and oil seeds are cultivated.

Plants of these climate resilient native rice varieties have long vertical roots, no lateral roots with least leaf curling (drought stress). Plants of the short duration variety normally are drought tolerant to some extent. Navdanya is conserving 39 drought tolerant rice varieties in Odisha.

## Drought resistant aromatic and therapeutic rice varieties

Besides, there are two other unique rice varieties, such as Differently Aromatic rice varieties (plenty) and Therapeutic (medicinal) rice varieties (few). Aromatic rice varieties have the ability to sustain in water deficit conditions (semi drought) unlike other normal longer days duration paddy varieties. Therapeutic rice varieties also sustain drought to considerable extent. Navdanya has conserved 55 aromatic and 2 therapeutic rice varieties in Odisha. These varieties have been produced through the Darwinian factors as Natural selection and Artificial selection with mutation over centuries.

Climate resilient Odisha rice varieties have performed exceedingly well on introduction in disaster areas such as Ersama in Odisha, Nagapattinam in Tamil Nadu and in Indonesia with respect to their tillering behaviours; 10 in Balasore, 14 in Ersama, 35 in Nagapattinam and 54 in Indonesia. (Last 2 under SRI method of cultivation). Currently in Odisha we are conserving 804 varieties of native Paddy, of these 184 varieties are climate resilient.

Hundreds of quintals of seeds of flood and salt tolerant diverse rice land races from Navdanya's Odisha Seed bank and Seed keepers have been provided to disaster hit farmers in post Orissa super cyclone at Ersama and Astarang in Odisha, post Indian ocean tsunami at Nagapattinam in Tamil Nadu, Nandigram in West Bengal and also to Indonesian farmers. In 2013 after the massive destruction of standing rice crop in coastal Odisha by cyclone Phailin, Navdanya also distributed 20 flood and salt tolerant indigenous rice seeds to farmers of Balasore and Mayurbhanj districts.

Navdanya was able to save climate resilient seed varieties throughout the country. During last more than 2 decades of our experience of working with farmers in different agro-ecological zones confirm that the farmers need to use native seeds which not only require much less water, but also are also resilient to diverse environment and are capable of withstanding in different climatic stresses.

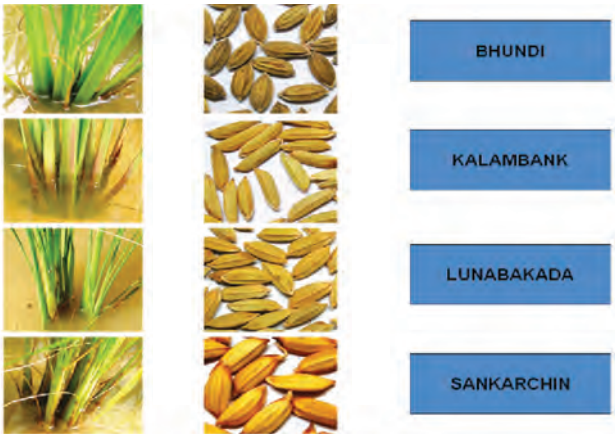
Navdanya in August 2006 established seed banks in Jaisalmer (drought resistant crops), Orissa (saline, drought and flood resistant rice) to help with various dimensions of preparedness in the face of extreme climate changes like the foods in Barmer (Rajasthan). In the year 2007 Navdanya established a seed bank at village Bajkul under disaster hit Nandigram block in Midinapur district of West Bengal. In these community seed banks Navdanya is saving and multiplying indigenous climate resilient varieties of different crops. We are currently multiplying seeds of cereals, millets, pseudo cereals, pulses, oilseeds, fruits and vegetables.

Climate resilient Odisha rice varieties have performed exceedingly well on introduction in disaster areas such as Ersama in Odisha, Nagapattinam in Tamil Nadu and in Indonesia with respect to their tillering behaviours; 10 in Balasore, 14 in Ersama, 35 in Nagapattinam and 54 in Indonesia. (Last 2 under SRI method of cultivation). Currently in Odisha we are conserving 804 varieties of native Paddy, of these 184 varieties are climate resilient. Climate resilient varieties conserved by Navdanya in Odisha are given below:

## Salt tolerant rice varieties

In Odisha the seasons have become unpredictable; the quantum and frequency of rains, droughts and saline inundations have increased substantially. Consequently, paddy as a crop is getting affected, but it is more so with the so called hybrids and high yielding varieties. However, the climate adapted rice varieties so evolved naturally sustain the impacts of climate change and maintain yield. Photo above (Sartha estuary, Orissa) substantiate the above statement. Researches currently being carried out in India and abroad to develop climate tolerant rice varieties is unnecessary. Conservation and propagation of the climate adapted varieties is necessary.

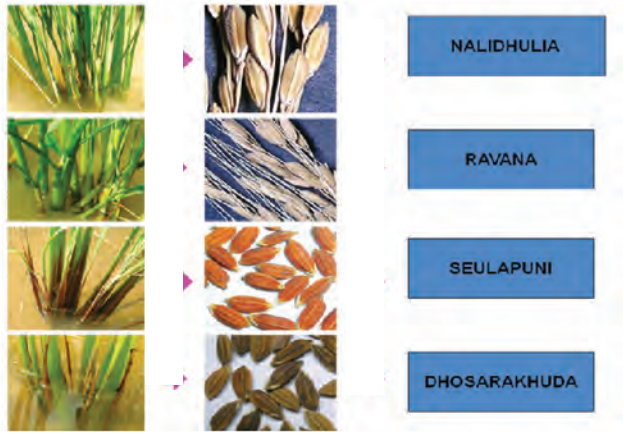
**PPBSA - NAVDANYA, ORISSA ACCESSION AND CONSERVATION OF SALT TOLERANT RICE VARIETIES**




## Flood Tolerance

The rice as a crop was brought from the arid areas to the coastal plains centuries ago. The tall indica rice varieties, thus evolved, have the ability to survive submergence. Some varieties are more able to withstand complete submergence for days together. A gene named "sub IA" has been identified in these rice varieties. Such genes have been evolved naturally in these rice varieties which are cultivated in predominantly sub merged coastal flood plains of Orissa where the crop plants remain wholly under water for days together yet survive to hand over a good yield.

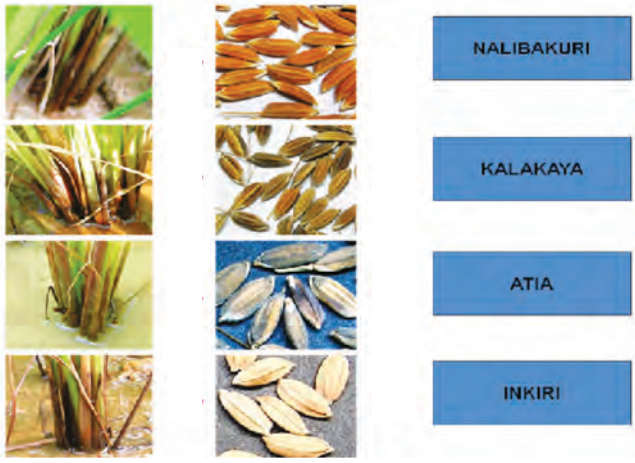
**PPBSA - NAVDANYA, ORISSA ACCESSION AND CONSERVATION OF FLOOD TOLERANT RICE VARIETIES**




## Drought tolerant rice

Orissa is endowed with some drought tolerant rice varieties, a few of which are of high therapeutic impotence. Drought stress crops exhibit inhibition of lateral root development as an adaptive response to the stress. The drought response is mediated by a gene that produces the phyto–hormone, "abscisic acid" which prevents lateral root development. Drought tolerant rice varieties do not exhibit much tillering and are of shorter day durations.

**PPBSA - NAVDANYA, ORISSA ACCESSION AND CONSERVATION OF DROUGHT TOLERANT RICE VARIETIES**




## Seeds of Hope for natural calamities

Seeds of Hope (AshaKeBija) program of Navdanya aim at providing an emergency supply of indigenous varieties of seeds in those regions, which are worse effected, either by the natural calamities or as result of the policies. Under the program, Navdanya continues its efforts to supply seeds to those who are in the need of it and have lost their local varieties due to natural disaster or Green Revolution policy of the government.

## Orissa super cyclone 1999

During the Odisha super cyclone in 1999 Navdanya provided the victims with total of 100 quintals of pad-

Seeds of Hope for Ersama,
victims of Odisha Super Cyclone

dy seeds of 14 varieties of native and nativised paddy in 3 devastated villages, namely Talang, Dharijan and Junagari under Gadabishnupur GP in Ersama block of Jagatsingpur district on 27th May 2000 through the ChachakhaiYubakSangh and one such village, Manduki under Astranga block of Puri district on 28th May 2000. Other than paddy native vegetable seeds were also given to the farmers and district administration for free distribution.

## Tsunami, 2004

During Tsunami in the year 2004 NavdanyaOdisha gifted 100 quintals saline resistant native paddy diversity of 3 varieties to the Joint Director of Agriculture, Nagapattinam, Tamilnadu for free distribution of on 9th July 2005 at Nagapattinam.

## Nandigram, 2007

In the year 2007 - Established a seed bank at village Bajkul under disaster hit Nandigram block in Midinapur district of West Bengal with 10 quintals of 5 saline resistant native paddy varieties through the Taj Group of volunteers led by Sk. AhmmadUddin on 31st May, 2007.

## Sartha, 2007

During the year 2007- Distributed 10 quintals of 8 saline resistant paddy varieties among 80 deluged families of SarthaPanchayat under SadarBalasore block among the beneficiaries on 22nd July, 2007 at the Mangrove Field Office, Sartha.

## Phailin, 2013

After the massive destruction of standing rice crop in coastal Odisha in 2013 by cyclone Phailin, Navdanya distributed 100 quintals of 20 flood and salt tolerant indigenous rice seeds to 400 farmers of Balasore and Mayurbhanj districts.

## Nepal earthquake 2015

On the 25th of April 2015 an earthquake of 7.6 Richter's struck Nepal. The aftershocks followed and a second quake measuring of 7.3 Richter's struck on the 12th of May killing over 9000 people. Navdanya provided about 2000 farmers with seeds of paddy, maize, millets and vegetables.

## Seeds of Hope, Gardens of Hope with widows of Maharashtra and Punjab

"Seeds of Hope - Gardens of Hope" program was started by Navdanya to address the food issue with the widows of the suicide victims of Vidarbha and Punjab. In this program, Navdanya encourages widows to start kitchen garden, and grow vegetables, fruit trees, herbs and medicinal plants for food and nutritional security. These gardens are a live example of biodiversity. The kitchen garden ensures food and nutrition. It has an added advantage of creating a cool microclimate in the scorching heat of Vidarbha and Punjab. The surplus is bartered with the neighboring households. After the fruit or vegetable is matured it is harvested and dried appropriately for the seed. The women keep some seeds for the next season and a portion is given to stock up the seed bank. Navdanya provided the seeds to these women in the begining whereas, now they have started saving their own seeds and are given seeds when they really need them. These women are empowered through and organizing them in groups and trainings in organic farming, seed saving and value addition to the raw material available in their surroundings, so that they can earn more money from the available resources.

This process has helped women in Vidarbha to become providers of seed and food. Minimum of 12 kinds of vegetables with multiple varieties of each are grown by the women farmers in these gardens, namely: Spinach, Fenugreek, Brinjal, Tomatoes, Chillies, Sorell, Bitter gourd, Cucumber, Cluster bean, Mustard, Onions and Coriander.

In Punjab women have started growing vegetables in their kitchen gardens now. In Punjab kitchen garden concept was totally forgotten by the communities, which Navdanya is trying to revive so that women and child get required nutrition from the kitchen garden by growing and then consuming vegetables and herbs.

## Genetic engineering and biopiracy of climate resilience in farmers varieties:

Genetic engineering is embedded in an industrial model of agriculture based on fossil fuels. It is falsely being offered as a magic bullet for dealing with climate change.

Monsanto claims that Genetically Modified Organisms are a cure for both food insecurity and climate change and has been putting the following advertisement across the world.

"9 billion people to feed.
A changing climate
Now what?
Producing more
Conserving more
Improving farmers lives
That's sustainable agriculture
And that's what Monsanto is all about."

All the claims this advertisement makes are false. GM crops do not produce more. While Monsanto claims its GMO Bt cotton gives 1500 Kg/acre, the average is 300–400 Kg/acre. Genetic engineering does not "create" climate resilience. In an article titled, "GM: Food for Thought" (Deccan Chronicle, August 26, 2009), Dr. M.S. Swaminathan wrote "we can isolate a gene responsible for conferring drought tolerance, introduce that gene into a plant, and make it drought tolerant."

Drought tolerance is a polygenetic trait. It is therefore scientifically flawed to talk of "isolating a gene for drought tolerance." Genetic engineering tools are so far only able to transfer single gene traits. That is why in twenty years only two single gene traits for herbicide resistance and Bt. toxin have been commercialized through genetic engineering. One was supposed to control weeds, the other to control pests. Both have failed.

Navdanya's report titled, "Biopiracy of Climate Resilient Crops: Gene Giants are Stealing farmers' innovation of drought resistant, flood resistant and salt resistant varieties," shows that farmers have bred corps that are resistant to climate extremes. And it is these traits which are the result of millennia of farmers' breeding which are now being patented and pirated by the genetic engineering industry. Using farmers' varieties as "genetic material," the biotechnology industry is playing genetic roulette to gamble on which gene complexes are responsible for which trait. This is not done through genetic engineering; it is done through software programs like athlete. As the report states, "Athlete uses vast amounts of available genomic data (mostly public) to rapidly reach a reliable limited list of candidate key genes with high relevance to a target trait of choice. Allegorically, the Athlete platform could be viewed as a 'machine' that is able to choose 50–100 lottery tickets from amongst hundreds of thousands of tickets, with the high likelihood that the winning ticket will be included among them."

Breeding is being replaced by gambling, innovation is giving way to biopiracy, and science is being substituted by propaganda. This cannot be the basis of food security in times of climate vulnerability.

Corporations have taken more than 1500 Climate Resilient patents for crops. The spin is that these traits are being genetically engineered. The reality is Biopiracy. Unlike farmers who knew what they were doing when they selected and bred for specific traits, the corporations have no idea. They are doing genomic mapping through computer programmes, doing guesswork about which part of the genome contributes to which trait, taking patents, hoping to collect trillions in royalties as climate change increases the need for these traits.This is a mega Seed Grab of the worlds climate resilient seeds,like the land grab in Columbus' time.

Evogene Ltd. (Israel) has patented a computer programme for reading the genome. Evogene's proprietary in silico "gene discovery technology" is called the "ATHLETE." 29 (In silico, as opposed to in vivo or in vitro, refers to investigations performed through the use of a computer or computer simulation).

ATHLETE is the company's proprietary computer database and analysis program for finding gene function by comparing sequences from as many different plant species, tissues, organs, and growth conditions as possible. Evogene says its database consists of 8 million expressed sequences, 400,000 "proprietary gene clusters," and 30 plant species. The program clusters sequences according to a variety of criteria, and then determines which gene candidates to investigate further. It is an informed winnowing process.

Evogene's website describes the platform it uses to identify key genes: "Athlete uses vast amounts of available genomic data (mostly public) to rapidly reach a reliable limited list of candidate key genes with high relevance to a target trait of choice. Allegorically, the Athlete platform could be viewed as a 'machine' that is able to choose 50-100 lottery tickets from amongst hundreds of thousands of tickets, with the high likelihood that the winning ticket will be included among them."

Evogene also collaborates with Monsanto (USA, the world's largest seed corporation). A deal struck between the two companies gives Monsanto exclusive rights to a number of genes identified by Evogene that reportedly allow crops to maintain stable yields with lower applications of nitrogen. The companies also collaborate on drought tolerance.

Monsanto and BASF (the world's third ranking agrochemical company) are investing $1.5 billion on collaborative R&D to develop high yielding crops that are more tolerant to adverse environmental conditions such as drought.

The colossal collaboration, perhaps the biggest joint biotech R&D program on record, will focus on stress tolerant traits for maize, soybeans, cotton and canola. The focus on these four commodity crops is not surprising because they are the crops that account for virtually all the world area planted in commercial GM plants.

It also collaborates with Dupont and Syngenta

At the end of 2007 DuPont announced a new collaboration with Evogene Ltd. (Israel) that will give DuPont exclusive rights to several drought-resistant genes "discovered" by Evogene for maize and soybeans. (from Biopiracy of Climate Resilient crops, Navdanya and ETC.)

A transition to biodiversity-intensive, ecologically-intensive agriculture addresses both the climate crisis and the biodiversity crisis simultaneously, while also addressing the food crisis. Even though industrial agriculture is a major contributor to climate change and more vulnerable to it, there is an attempt by the Biotechnology industry to use the climate crisis as an opportunity to further push GMOs, and to deepen their monopoly on global seed supply, through *biopiracy*-based patents on climate resilient seeds, that were bred by farmers over generations. Climate resilient traits will become increasingly important in times of climate instability and in the current system, will allow corporations to exploit the farmers and consumers by owning the rights to these plants.

While genetic engineering is a false solution, over the past 20 years, we have built Navdanya, India's biodiversity and organic farming movement. We are increasingly realizing there is a convergence between objectives of conservation of biodiversity, reduction of climate change impact and alleviation of poverty. Biodiverse, local, organic systems produce more food and higher farm incomes, while they also reduce water use and risks of crop failure due to climate change.

Biodiversity offers resilience to recover from climate disasters. After the Orissa Super Cyclone of 1998, and the Tsunami of 2004, Navdanya distributed seeds of saline resistant rice varieties as "Seeds of Hope" to rejuvenate agriculture in lands reentered saline by the

sea. We are now creating seed banks of drought resistant, flood resistant and saline resistant seed varieties to respond to climate extremities.

There is a desperate attempt by the Biotechnology industry and by the Gates Foundation to use the climate crisis to as an opportunity to further push GMOs, and to deepen their monopoly on the seed supply through biopiracy patents on climate resilient seeds.

GMOs and patent monopolies are not the answer to mitigating or adapting to climate change, or reversing biodiversity erosion, because they are embedded in chemical monocultures and centralised monopolistic control over the seed supply. Chemical agriculture and a globalized food system is responsible for 40-50% of all green house gas emissions that contribute to climate change as I have written in my book, Soil, not Oil. And chemical monocultures are also more vulnerable to failure in the context of an unstable climate. Centralised systems are also more vulnerable to collapse in times of climate extremes.

Adapting to an unpredictable climate change requires diversity at every level. Biodiverse systems are more productive in terms of nutrition per acre, and also more resilient in times of climate change. Decentralised systems have more flexibility to respond. That is why we promote community seed banks at the local level.

We also need biodiversity at the level of knowledge systems. The mechanistic paradigm which is blind to systems linkages has pushed humanity towards an ecological catastrophe. We cannot depend on the mechanistic mind and its unscientific denial of the sciences of the interconnected nature of living systems and ecosystems to get us out of the crisis. As Einstein said 'We cannot solve a problem with the same mindset that created it'.

Biodiversity of knowledge implies that we recognise the ever evolving knowledge of women, farmers, tribals, citizens which comes from their life experience and their intimate connection with the Earth and local ecosystems and Biodiversity. We need to recognise the emerging sciences of agroecology and epigenetics. The field of epigenetics is telling us that the genetic dogma that DNA is a master molecule, and information travels unidirectionally from the DNA to the RNA is an outmoded assumption. This is the dogma on which genetic engineering is based.

Research in epigenetics is showing us that environmental, nutritional and social influences affect the behaviour of genes. Hence we need a Systemic, not a reductionist framework for science.

At the ecosystems level, Agroecology is also a systems paradigm. This is the real science of agriculture and food production, not biotechnology.

We also need biodiversity in our economic activities. We need local food systems, regional food systems, national food systems, and some trade can take place at the international level. Today everything is global trade, controlled by a handful of Multinational Corporations.On the one hand this economic monoculture contributes to climate change, and on the other it is vulnerable to breakdown.

Finally we need Biodiversity of political systems and decision making. Centralised and bureaucratic systems are like dinosaurs. They are not flexible and cannot adapt and evolve.

We need flexibility, which comes from diversity. Biodiversity in politics is what I call Earth Democracy.

*How the Gates Foundation Presents the Biopiracy of Flood Tolerant Rice as "Innovation"*

> Problem: In areas of Asia and Africa where rice-growing farmers depend on rain fed agriculture, rice productivity is low and unstable due to stresses such as flooding, drought and poor soils.
>
> Flooding regularly afflicts over 6million hectares in South Asia and as much as one-third of the rain-fed lowland rice-growing areas in sub-Saharan Africa.
>
> Neither newer rice varieties nor farmers' traditional varieties are able to survive prolonged submergence under water.
>
> There's a need for new rice varieties that can withstand a range of environmental stresses.
>
> Innovation: Harness the knowledge of leading global, regional and national agricultural researchers and combine it with local know-how to develop and distribute submergence-tolerant rice to small farmers.
>
> Through Stress Tolerant Rice for Africa and Asia (STRASA), the International Rice Research Institute (IRRI) partners with researchers at the Africa Rice Center, an African research organisation, and national scientists in poor countries, creating submergence-tolerant rice varieties that can "hold its breath" underwater.

STRASA developed improved varieties through identifying and using traits that allow rice to make better use of oxygen even while submerged--coping with this stress that can devastate crops.

At the Milan Expo 2015, during the Women's conference organised by Emma Bonino, Italy's former foreign Minister,I was invited to give a keynote address. In a panel following my address, a representative of the Gates Foundation talked of how the Foundation was financing the innovation and invention of climate resilient crops through new technologies. When I asked him which farmers varieties they were using, he was silent.

Climate resilience is a complex trait, and cannot be "engineered" through the crude tools of transferring single gene traits from one organism to another.

What corporations and the Gates foundation are doing is taking farmers varieties with known climate resilient traits from public gene banks, mapping their genome, and taking patents on the basis of guesswork and speculation, about which part of the genome contributes to the known trait.

Like Columbus -- setting out for India, getting lost and arriving in the Americas, "discovered" "America" -- Gates and Monsanto are "discovering" climate resilience.

Just as the narrative of Columbus' Discovery erases the indigenous people who lived across the American continent, as well as those who had travelled before Columbus, the patenting of climate resilience erases farmers breeding, and the biodiversity which they have given us. It erases the source of the seed,the culture of the seed, the commons of the seed. It is an enclosure through piracy - Biopiracy.

Patenting life through genetic engineering is rapidly giving way to patenting life through mapping the genome, very much like Columbus' "discovery" of America. Navdanya's Community Seed Bank in Orissa has conserved more than 800 rice varieties and multiplied and distributed salt tolerant varieties and flood tolerant varieties.

The "innovation" to evolve these climate resilient traits has occurred cumulatively and collectively over thousands of years. These traits and crops are a commons. However, the traits evolved by nature and farmers over centuries are now being presented as the "invention" of "scientists", who rename the flood tolerant property in the farmer's variety such as "Dhullaputia" from Orissa as the Sub1A or the submergence tolerant gene. "Using marker-assisted selection (not transgenics) the researchers were able to isolate the submergence tolerant gene, Sub1A, and then transfer it to a rice variety that is grown on more than 5 million hectares in India and Bangladesh, known as Swarna. Most rice can tolerate flooding for only a few days, but researchers say the new variety, Swarna-Sub1, can withstand submergence for two weeks without affecting yields".

This is scientifically flawed description, based on genetic reductionism,because flood tolerance, like other climate resilient traits such as salt tolerance and drought tolerance,aremultigenetic traits, they cannot be identified as a "Sub1A gene". Because it is not "a gene" it has been referred to as "Submergence tolerance 1 (Sub1) Quantitative trait locus (QTL)"

What marker assisted selection does is identify the genetic sequence that is always linked to varieties which share a trait.

http://www.greenpeace.org/australia/PageFiles/348427/smart-breeding.pdf

Such varieties are then selected for crossing conventionally with varieties like Swarna. Farmers who have bred the traits did not need MAS to breed for climate resilience. This is why we need to recognise the diversity and pluralism of knowledge systems and diversity of languages to describe and name processes and organisms.

The Agrichemical and Biotech industry is now using the climate resilient crops bred by farmers to do their genomic mapping and claim the farmer bred traits as their inventions through patents. This is not breeding. It is Biopiracy, Piracy.

Gates steals centuries of breeding by farmers and describes it as New flood-tolerant rice offers relief for world's poorest farmers. This is how the Gates Foundation redefines the Biopiracyof Flood Tolerant Rice from India farmers as "Innovation" funded by Gates - farmers as breeders disappear and as the source of flood tolerant traits disappear. They become recipients of the which came from them in the first place. This is the regime of BioNullius, building on the concept of Terra Nullius –that farmers minds are "empty", and their seeds "empty". "innovation" begins when Gates and Big Money takes over.

## Biopiracy is theft, not innovation

Seed has emerged as the site of ethical, ecological, ontological, scientific, legal, economic and political conflict between two world views and ontologies. One world-view is based on the mechanical mind, and the money machine, which creates the illusions of corporations as "persons" with "minds" that create and own "life" as intellectual property for corporate profits. The second world view is based on the recognition of the self organising, intelligent and self propagating nature of life forms, including seeds; of intelligent, creative, compassionate humans sharing the Earth with the diversity of life forms and all beings as an Earth Family- "*Vasudhaiv Kutumbkam*."

Through patents on seeds and life forms, a new ontology is being created. The nature of being and existence is being redefined in such fundamental ways that life itself is threatened. When corporations, that were designed as legal constructs, claim "personhood", it is real people – who stand in line at polling booths, eke out livelihoods, and raise families - who lose their rights. By outlawing the availability of renewable, open-pollinated seeds, corporations selling non-renewable patent- ed seeds would be able to force everyone, from large scale farmers to a balcony gardener, to buy only the seeds they sold, every year, ensuring an absolute monopoly and an end to our diversity.

Monopolistic control over seed has been the objective of industrial agriculture corporations throughout the last half-century. The main instruments used in imposing ownership of seed are patents and, the misleadingly named, Plant Breeder's Rights or Plant Variety Protection laws - which in fact are "Soft Patents" - an alternative to patents used in situations where the introduction of patents would face strong resistance from the people. Soft patents have been used to deny farmers their rights to save and share seed, and to enable corporations to establish "Soft Monopolies" until they can enact laws that enable them to cement their monopoly and through the monopoly, establish *Seed Slavery*.

We are witnessing the establishment of monopolies over seeds through patents, mergers and cross licensing arrangements. Large agrichemical businesses have joined together, as a cartel having agreements to share patented genetically engineered seed traits amongst themselves, for total control over the seed supply and a total destruction of the very foundations of agriculture. 100% of the GM seed planted in the world is controlled by just six American and European companies - Monsanto, DuPont, Syngenta, Dow, Bayer and BASF - all originally, and mainly, chemical corporations. DuPont and Monsanto have settled their patent infringement suits against each other, making clear that the patents they hold are only to extract profits from the farmers and people of the world and not to protect their 'intellectualproperty' or 'foster innovation'2. These giant chemical and seed corporations are not competing with each other, they are fighting against peasants and farmers. Quite clearly, this seed cartel is one giant monopolistic entity with the common ambition of totalitarian control over our seeds and food.

Monsanto's goal was to privatise and colonise all seed, everywhere, by the year 2000 - quite obviously, it has failed miserably at achieving this stated goal. Having failed at their first attempt at outright control because of the rise of Seed and Food Movements across the world, movements that have built alternatives which are obstacles to these corporate objectives, corporations are criminalising these alternatives, especially people's seeds - evolved and tested by farmers over centuries. In 2004, simultaneously in India and the US, new laws were proposed based on Li- censing and Registration in an attempt to destroy non-corporate sources of seed. The Indian bill did not become law because of resistance from the seed movement in India, but in the US it became law and is being used to serve notices to seed savers and seed libraries across the US today.

In 2014, India's patent office rejected Monsanto's patent application for climate resilient traits of cold tolerance, salt tolerance and drought tolerance that our farmers have evolved over millennia, through applying their knowledge of breeding. Responding to Climate Change requires rejuvenation of Biodiversity, regeneration of living soils with living carbon through Agroecology and organic farming, It also needs the rejuvenation of our Biodiversity and Knowledge commons. The corporations that have destroyed our biodiversity and privatized it through patents, have also privatized the atmospheric commons and driven catastrophic climate change. They are now privatizing climate data, soil data, genetic data, and trying to creatre new commodities through "Big Data".

Climate resilience depends on our saving and spreading the Seeds of Hope, the Seeds of Freedom, the Seeds of Resilience.

# *Vasudhaiva Kutumbukam*

# The Earth Family

***Vasudhaiva Kutumbkam:***
***Seeding Freedom***
***No Patents on Seed***

We are the children of
*Vasudhaiva Kutumbkam,*
the Earth Family.
We have a duty to protect our relatives, to protect the plant and animal diversity that enrich our lives with beauty and nourish us.
Humans do not invent and create life on Earth.
Humans cannot own plants and animals through patents.
We are proud citizens of a sovereign country which has laws that defend our seed, our land and our Mother Earth.

**#NoPatentsonLife**

Article 3(j) of our Patent Act excludes from patentability "plants and animals in whole or in any part thereof other than microorganisms but including seeds, varieties, and species, and essentially biological processes for production or propagation of plants and animals"

These laws protect our future and the future of our Earth Family
They protect the rights of our farmers who grow our food
Giant chemical corporations producing poisons have spread diseases, killed our bees, butterflies, earthworms and pushed **300,000 farmers to suicide** due to debt.

They are now challenging every law of India:
The Patent Act, Plant Variety & Farmers Act, Competition Commission, Essential Commodities Act.
Every one of these acts creates the framework for our security and freedom

**It is our right to grow up in a Free Independent, Sovereign, Democratic Republic called India**
**#NoPatentsonSeed**

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# APPENDIX I

## A study on Effect of continuous farming on Soil under Organic and Chemical mode

A comparative study of soil microbes and nutrients both in chemical and organic farming was done. To understand the soil health under continuous cultivation after using organic and chemical inputs, a survey was conducted in different states namely: Uttarakhand including Navdanya farm and surrounding villages, Balasore district in Odisha, Banda district in U.P., Ajmer district in Rajasthan and Vidharba in Maharashtra where farmers were selected who were practicing both chemical and organic inputs under different crops at least more than 5 years.

Detailed study of the effect of most important crops on biological parameters like bacteria and fungi population and physico-chemical parameters like Organic matter, Total Nitrogen and available P and K was done in the few crops growing in Uttarakhand i.e. Wheat, Potato, Garlic, Mustard, Chick pea, Chilli and Pumpkin is given below. The microbial population especially fungi, bacteria, was significantly higher under organic farming areas than chemical farming. There was reduction in organic matter content of the soil under all the crops growing in chemical farming whereas increase in organic matter content under organic farming soil varies between 26-99%. A significantly higher total N and available K content were observed under organic farming practice. The results clearly showed that organic farming has a great role to maintain excellent soil health and nutrient content in the soil.

### A. Biological parameters

**1. Fungi population:** The fungi population on different crops was increased over control soil between 6 and 36 fold (Table 1) when organic farming was practiced, which was much less under chemical farming (Fig 1). Except mustard, all other crops showed decline in fungal population under chemical farming than no input cultivation. The mustard field showed there was 59.7% improvement in the population under chemical farming which was enhanced to 14-47% further under organic farming.

**Table 1. Fungi (CFU x 10 $^{3}$/g) population under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 5.5 | 22 | 20.0 | 66.5 |
| Potato | 3.5 | 7 | 6.0 | 120.0 |
| Garlic | 7.0 | 20 | 19.5 | 94.0 |
| Mustard | 3.0 | 7.2 | 11.5 | 111.0 |
| Chick pea | 6.5 | 18.7 | 8.0 | 180.0 |
| Chilli | 8.5 | 20 | 14.0 | 160.0 |
| Pumpkin | 7.0 | 14.1 | 12.0 | 52.0 |
| LSDp(=0.05) | 4.2 | 7.3 | 6.5 | 11.1 |

*barren land, no crops

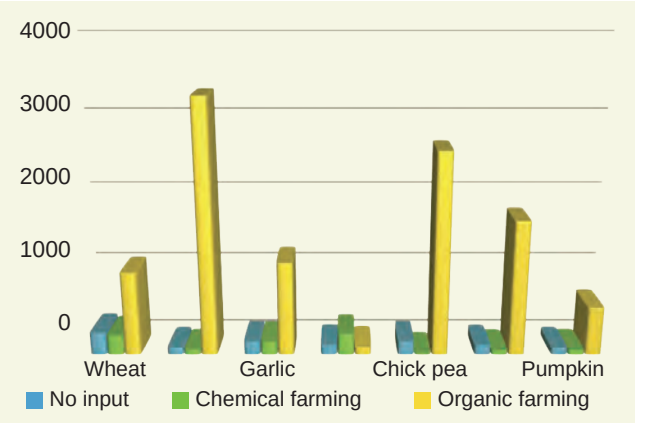



Fig 1. Status of Fungal population (CFU x $10^{3}$ g-1) under different crops and farming practices

The reduction in fungal population due to chemical farming varies between 2.5-49.7% under different crops than no input agriculture (control). However, upto 16 fold improvement in fungal population was noticed due to organic farming practice when compared with no input crops (Fig.2).

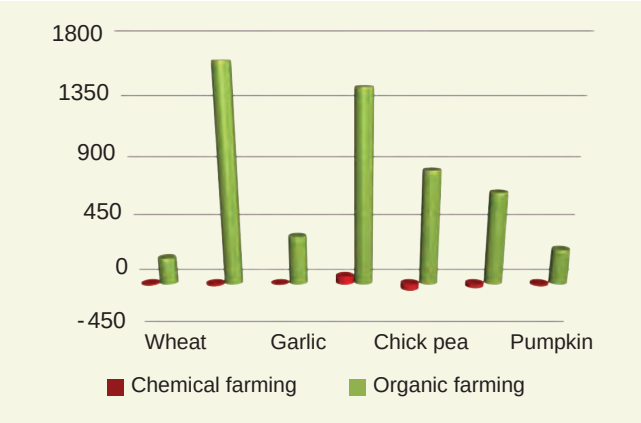



Fig 2. Changes in fungi population under chemical and organic farming

**2. Bacteria population:** Organic farming enhances bacteria population between 1.8- 6.2 fold under different crops (Table 2), which was 78% more build up than chemical farming. In general, 50-241% increase in bacteria population was observed under organic farming over no input land (Fig 3).

**Table 2. Bacteria (CFUx10 $^{5}$/g) population under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 2.5 | 4.4 | 4.0 | 15.0 |
| Potato | 3.0 | 8.4 | 8.0 | 12.0 |
| Garlic | 4.5 | 10.4 | 7.0 | 26.0 |
| Mustard | 3.5 | 6.0 | 4.0 | 10.0 |
| Chick pea | 5.0 | 9.3 | 7.0 | 14.0 |
| Chilli | 2.0 | 5.8 | 5.5 | 12.5 |
| Pumpkin | 4.0 | 8.8 | 8.0 | 29.0 |
| LSD (p=0.05) | 1.7 | 1.9 | 1.8 | 3.5 |

*barren land, no crops

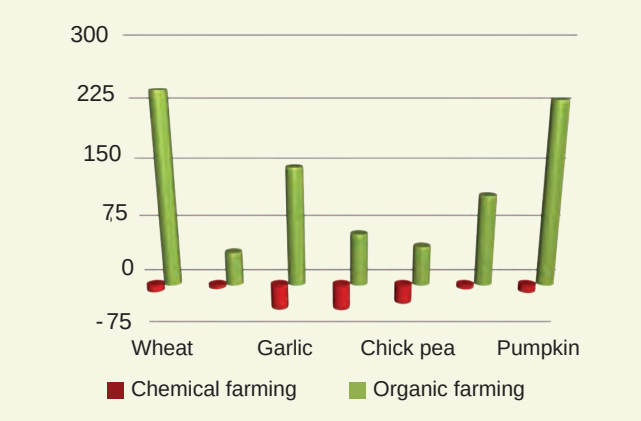



Fig 3. Changes in Bacteria population under chemical and organic farming.

The adverse effect of chemical farming in bacterial population was obvious and it was more alarming especially under mustard, chick pea and garlic (Fig 4). The population build up under organic farming was found to be very effective under wheat followed by pumpkin among the seven crops compared.

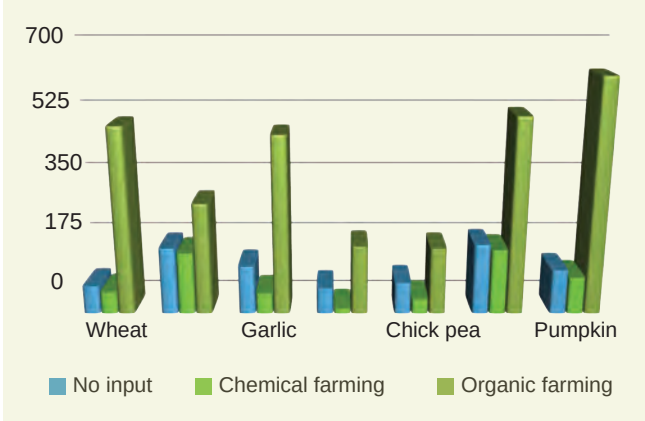



Fig. 4. Status of bacterial population (CFUx10$^{5}$ g$^{-1}$) under different crops and input practices

## B. Physio-chemical parameters

**1. Organic matter:** The build up of organic matter was much higher under different crops when organic farming was continuously practiced. The more build up was observed under mustard and garlic (Table 3). Plant contributed more on organic matter build up under wheat (33.3%), garlic (28.6%) and chick pea (23.1%) while least contribution was noticed under chilli 5.2% and potato 7.2%. In general, chemical farming resulted in reduction of organic matter build up by -14% under different crops, than no input land. The results showed 29-99% build up of organic matter over no input land due to organic farming practiced for a long time under different crops (Fig 5).

**Table 3. Organic matter (%) content under different crops and farming practices.**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.80 | 1.20 | 1.14 | 1.67 |
| Potato | 0.80 | 0.86 | 0.74 | 1.27 |
| Garlic | 0.85 | 1.19 | 1.17 | 2.21 |
| Mustard | 1.12 | 1.35 | 1.34 | 2.68 |
| Chick pea | 0.90 | 1.17 | 1.12 | 1.47 |
| Chilli | 0.92 | 0.97 | 0.95 | 1.62 |
| Pumpkin | 0.85 | 0.93 | 0.85 | 1.29 |
| LSD (p=0.05) | 0.11 | 0.18 | 0.15 | 0.21 |

*barren land, no crops

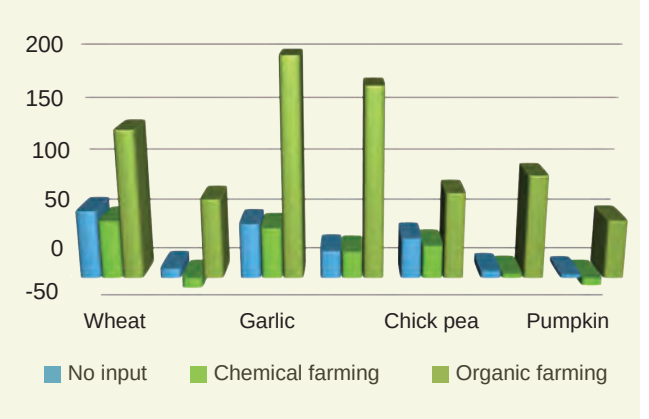



Fig 5. Status of Organic matter (%) under different crops and farming practices

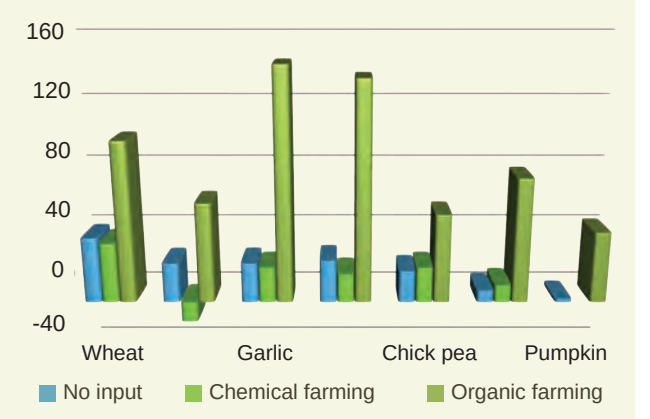



Fig 6. Status of Total N (%) under different crops and farming practices

**2. Total Nitrogen:** The total N content in soil under organic farming of seven different crops tested was varies between 44-147% (Table 4), which was more under garlic followed by mustard. Except potato and pumpkin, there was no change in total N under chemical farming when compared with no input soil. It decline in total N content between 7 and 22% was noticed when mustard and potato was grown under chemical input.

**Table 4: Percentage total Nitrogen (N) under different crops and farming practices**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.08 | 0.11 | 0.11 | 0.16 |
| Potato | 0.08 | 0.09 | 0.07 | 0.13 |
| Garlic | 0.09 | 0.11 | 0.11 | 0.22 |
| Mustard | 0.11 | 0.14 | 0.13 | 0.26 |
| Chick pea | 0.09 | 0.11 | 0.11 | 0.14 |
| Chilli | 0.09 | 0.10 | 0.10 | 0.16 |
| Pumpkin | 0.09 | 0.09 | 0.09 | 0.13 |
| LSD (p=0.05) | 0.03 | 0.02 | 0.04 | 0.05 |

*barren land, no crops

The present result suggested that to build up of N status in the soil, organic farming has major role than chemical farming or no input soil (Fig 6). In general, 21-100% build up of N content was observed under different crops were regularly organic farming was practiced. The more build up (100%) over no input land was noticed under garlic followed by mustard (85.7%) and chilli (60%).

**3. Available P:** Except for two crops (mustard and chick pea) organic farming enhances available P content upto 63% over no input soil. In general, very poor performance of plant contribution was noticed (5-17%) to build up available P under different crops. An erratic result was observed on available P status under chemical farming due to non uniformity of application under different farmers field condition but more available P build up under chemical farming was notice under potato followed by chilli while chick pea showed no change in available P status both under chemical and organic farming (Table 5).

**Table 5: Available P (mg/kg) under different crops and farming practices**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 21.1 | 24.3 | 28.2 | 33.6 |
| Potato | 25.5 | 30 | 71.8 | 43.7 |
| Garlic | 29.2 | 35.1 | 43.9 | 44.2 |
| Mustard | 28.7 | 34.6 | 46.1 | 30.0 |
| Chick pea | 24.0 | 25.4 | 25.3 | 24.9 |
| Chilli | 26.0 | 28.7 | 64.3 | 46.9 |
| Pumpkin | 27.2 | 31.3 | 35.0 | 38.7 |
| LSD (p=0.05) | 1.7 | 2.1 | 3.5 | 3.2 |

*barren land, no crop

In general, sharp improvement of available P status was observed both under chemical and organic farming when compared with no input crop. The effect was more under potato and chilli (Fig 7).

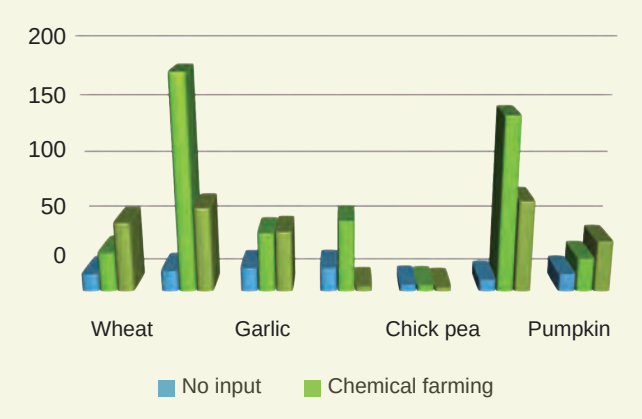



Fig 7. Status of available P (mg $kg^{-1}$) under different crops and farming practices

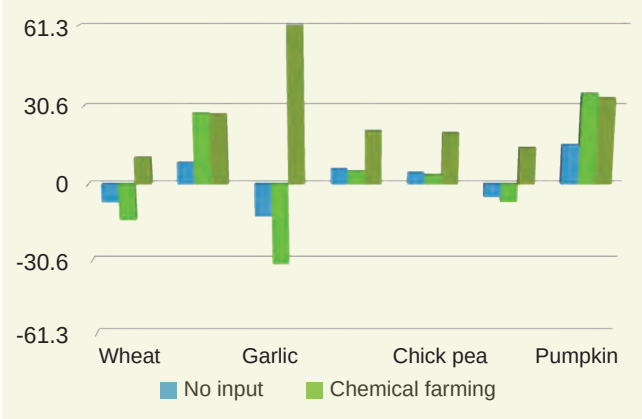



Fig 8. Status of available K (mg $kg^{-1}$) under different crops and farming practices

**6. Available K:** Although negative impact on available K status due to chemical farming, in general, was noticed but organic farming enhances available K status under all the crops tested crops between 14-84%. The more positive effect on organic farming over no input soil was notice under garlic (84.4%) followed by chilli (20.5%). Except potato and pumpkin, all other crops growing in chemical farming showed negative build up of available K which was maximum under garlic (-22.2%). The results (Table 6) also showed least plant contribution to build up available K status in the soil. The changes in available K status over absolute control were presented as Fig 8. The results clearly showed garlic builds more available K status in the soil when organic farming was practiced.

**Table 6: Available K (mg/kg) under different crops and farming practices**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 124.3 | 115.6 | 106.6 | 137.3 |
| Potato | 110.9 | 120.3 | 141.7 | 141.4 |
| Garlic | 108.8 | 95 | 73.9 | 175.2 |
| Mustard | 112.0 | 118.7 | 117.7 | 135.5 |
| Chick pea | 110.0 | 115 | 114.0 | 132.2 |
| Chilli | 108.0 | 102.6 | 100.5 | 123.6 |
| Pumpkin | 105.0 | 120.8 | 142.3 | 140.5 |
| LSD (p=0.05) | | | | |

*barren land, no crops

## A study on changes in biological soil health under Bt cotton growing areas in Vidharbha, Maharashtra

A detail survey was conducted to entire Vidharbha Bt cotton growing areas where at least ten different villages were selected for sampling under each districts of where both Bt and non-Bt cotton growing fields for last 10-12 years. A comparison was made on biological soil health under Bt, non-Bt and no crop lands. The results clearly indicate that under every district where Bt cotton was growing, a significant decline in all biological activities contributing to soil health like acid phosphatase, alkaline phosphatase, esterase, dehydrogenase, fungi, bacteria, nitrosomonas, nitrobacter and *azotobacter* population. The decline ranges between 6 and 77% of different parameters, which indicate the severe adverse effect of Bt cotton on soil biological health. Sometimes the activity under Bt cotton growing soils was less than the control soils (no crop soil) after continuous cultivation of 10-12 years, which was really alarming situation and needs to address the prompt remedy.

## Activity 1: Effect on continuous farming under organic and chemical mode

**Summary:** To understand the soil health under continuous cultivation after using organic and chemical inputs, a survey was conducted under Uttarakhand Navdanya farm areas where farmers was selected who were practicing both chemical and organic inputs under different crops at least more than 5 years. The effect of most important crops growing under Uttarakhand i.e Wheat, Potato, Garlic, Mustard, Chick pea, Chilli

and Pumpkin was taken into consideration. The results clearly suggested that a significant decline in most important soil enzyme activities like dehydrogenase, esterase, acid and alkaline phosphatase noticed under chemical farming as compared to organic farming. The microbial population especially fungi, bacteria, actinomycetes, azotobacter and nitrosomonas was significantly higher under organic farming areas than chemical farming. There was reduction in organic matter content of the soil under all the crops growing in chemical farming whereas increase in organic matter content under organic farming soil varies between 26-99%, although no significant changes in soil pH and EC was observed under different farming practices but a significantly higher total N and available K content was observed under organic farming practice. In general, micronutrient like Zn, Cu, and Fe content was significantly higher under organic farming in all the crops tested. The results clearly showed that organic farming has a great role to maintain excellent soil health and nutrient content in the soil.

**Background:** A survey work has been done at Uttarakhand (Navdanya farm surrounding areas) to understand the biological soil health in organic and chemical input growing areas. In general, between 8 and 20 years of continuous practice was considered for sampling. The soil samples were collected from the fields of 7 different crops growing under absolutely organic farming, chemical farming and non input condition. The soil samples collected from bunds (barren soils) was considered as absolute control; at least four farmer's field was selected for each type of cultivation under each crop. In general, the parameters were considered as Dehydrogenase, Esterase, Acid phosphatase, Alkaline phosphatase, population of Fungi, Bacteria, Actinomycetes, Nitrosomonas, Azotobacter, pH, EC, Organic Carbon, N, P, K, Zn, Fe, Cu and Mn.

## Results

### a) Beneficial Enzymes

1. **Dehydrogenase:** The dehydrogenase activity indicates the activity of bacteria and actinomycetes in the soils under different growing conditions. The dehydrogenase activity under organic, chemical and no input conditions of seven different crops studied was presented as Table 1.

**Table 1: Dehydrogenase activity (pkat/g) under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.79 | 1.55 | 1.52 | 2.35 |
| Potato | 0.80 | 1.48 | 1.43 | 1.79 |
| Garlic | 0.80 | 1.16 | 1.05 | 1.49 |
| Mustard | 0.79 | 1.39 | 1.13 | 3.16 |
| Chick pea | 0.79 | 1.00 | 0.80 | 1.45 |
| Chilli | 0.80 | 1.47 | 1.31 | 2.34 |
| Pumpkin | 0.78 | 0.92 | 0.71 | 1.28 |
| LSD (p=0.05) | 0.15 | 0.23 | 0.31 | 0.38 |

*barren land, no crops

The results (Table 1) clearly indicate that there was no significant difference in dehydrogenase activity in absolute control soil where no plants were growing. The dehydrogenase activity varies due to the farming practice and the crops under cultivation. The improvement in dehydrogenase activity, irrespective of crops, was much higher under organic than chemical farming (Fig 1). The much higher dehydrogenase activity (300%) was observed under mustard crop and the least improvement was noticed under pumpkin (64.1%) when compared with absolute control soil. In general, organic farming results 39-127% improvement in dehydrogenase activity when compared with chemical farming soils under the same crops in a similar soil condition.

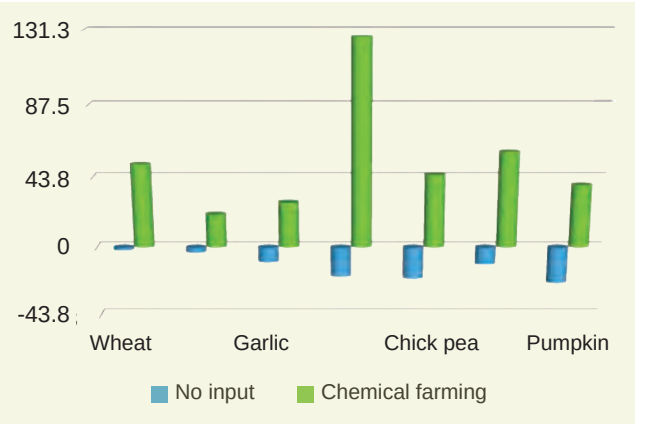



Fig 1. Changes in dehydrogenase activity under chemical and organic farming

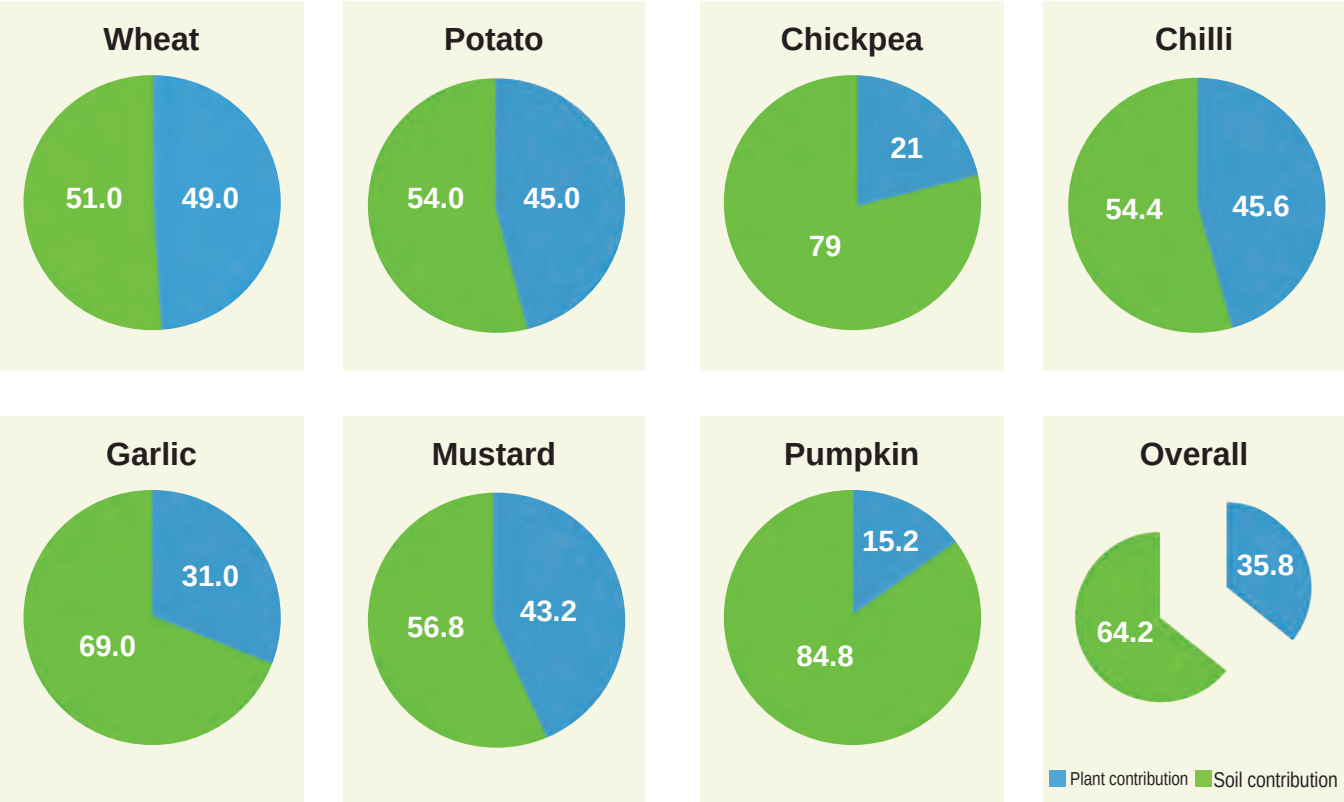



Fig 2. A comparison of plant and soil contribution towards Dehydrogenase activity

The negative impact of dehydrogenase activity (2-23%) was observed when compared with no input soil with chemical farming practices clearly indicate the clearly the adverse effect of chemical farming under different crops. When practiced the plant contribution and soil contribution of dehydrogenase activity, it was found that there was great variation among the crops. The soil contribution was found to be much higher, in general, than plant contribution (Fig 2). The overall results showed 64.2% activities of dehydrogenase contributed by soil and 35.8% were contributing by plants. In general, 18% decline in dehydrogenase activity (Fig 3) was observed when chemical farming was practiced as compared to no input (no chemical, no organic), which also clearly indicated that chemical farming has an adverse effect on soil dehydrogenase activity. The results (Fig 3) also showed that organic farming promotes dehydrogenase activity by 43% as compared to the crops growing under no input land. The most negative effect toward dehydrogenase activity under chemical farming was noticed on pumpkin followed by chickpea and mustard (Fig 1).

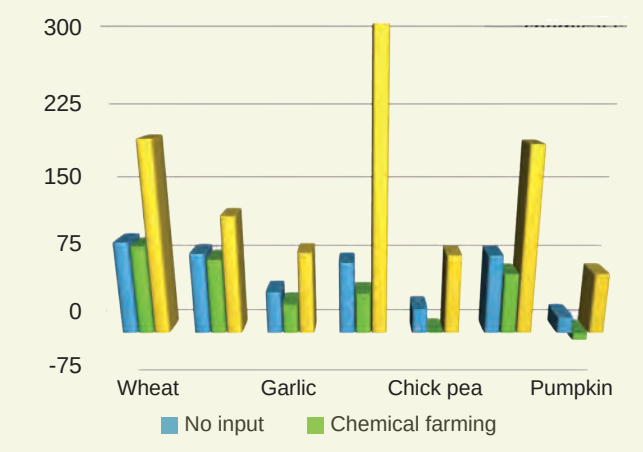



Fig 3. Status of dehydrogenase activity (pKat $g^{-1}$) under different crops and input practice

2. **Esterase:** Esterase activity indicates the activity of fungi, bacteria and actinomycetes in the soil under study. In general, 2-8.7 fold improvement in esterase activity was noticed under different crop rhizosphere (Table 2) due to organic farming practice which was more under wheat followed by mustard.

**Table 2: Esterase activity (EU x $10^{-3}$) under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 2.4 | 6.7 | 6.4 | 23.3 |
| Potato | 2.6 | 7.3 | 7.2 | 17.9 |
| Garlic | 2.8 | 9.7 | 9.4 | 22.6 |
| Mustard | 4.1 | 12.8 | 12.4 | 36.9 |
| Chick pea | 3.8 | 10.3 | 9.4 | 14.1 |
| Chilli | 4.2 | 7.8 | 6.9 | 20.7 |
| Pumpkin | 3.2 | 5.9 | 5.8 | 12.7 |
| LSD (p=0.05) | 0.9 | 1.3 | 1.9 | 2.1 |

*barren land, no crops

Although there was little difference in esterase activity under control soil of different crops it was but very clear from the result that a consistently higher in esterase activity (28-56%) under organic farming soils when compared with chemical farming, Chemical farming resulted up to 12% decline in activity as compared to absolutely no input land (Fig 4).

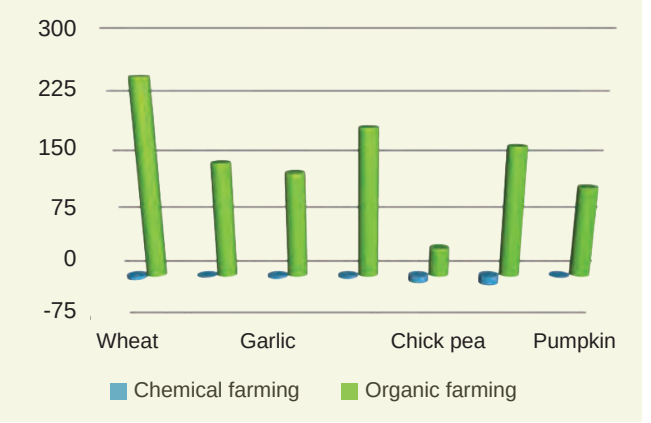



Fig 4. Changes in Esterase activity under chemical and organic farming

In general, 8.4% decline in esterase activity, irrespective of crops, was noticed under chemical farming as compared to no input agriculture. The decline in activity was much more under chick pea followed by chilli and wheat rhizosphere (Fig 5).

A comparison of plant and soil contribution towards esterase activity was made and it was found that 60.4% esterase activity was contributed by plants whereas soil contribution was only 39.6%. In general, more plant contribution was noticed under garlic and least under pumpkin whereas more soil contribution was noticed under chilli (Fig 6).

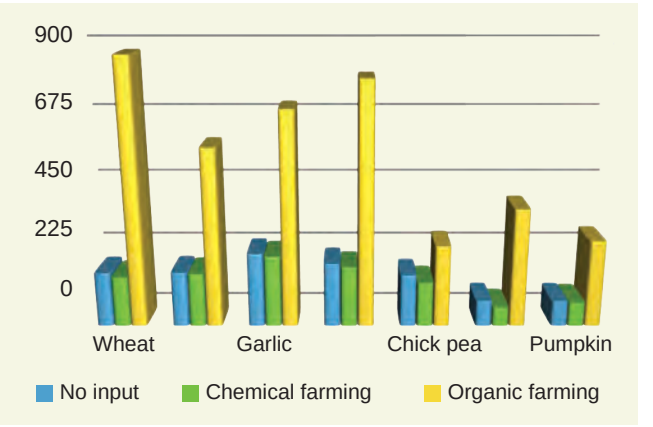
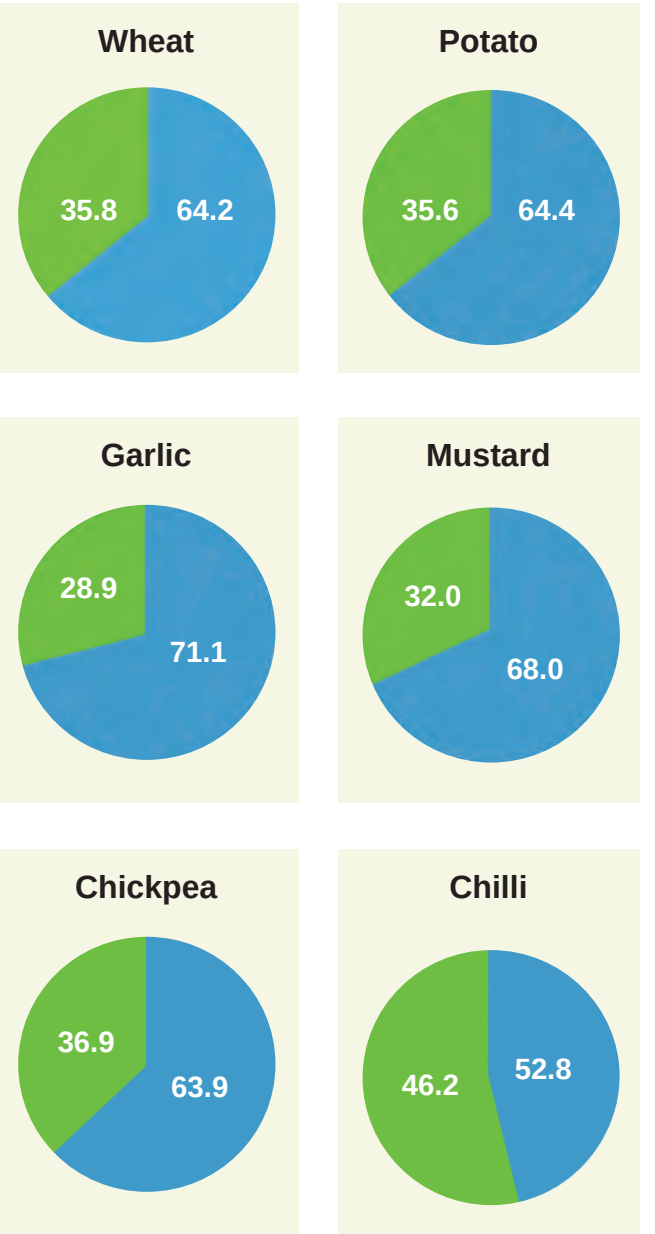



Fig 5. Status of Esterase activity (EU x $10^{-3}$) under different crops and input practice



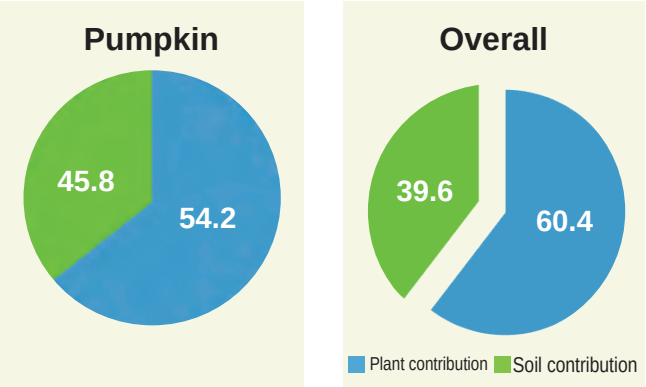



Fig 6. A comparison of Plant and soil contribution on Esterase activity

3. **Acid phosphatase:** Acid phosphatase mainly contributed by the plants and microorganisms in soil, Phosphatase enzymes helps in hydrolysis of C-O-P ester bond of organic phosphorus in plant available inorganic P in phosphate form. The activity of acid phosphatase under different input as well as seven crops was presented as Table 3.

**Table 3: Acid phosphatase (EU X $10^{-3}$) under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.6 | 1.8 | 4.0 | 4.2 |
| Potato | 0.8 | 2.8 | 3.2 | 3.9 |
| Garlic | 0.9 | 3.4 | 3.4 | 4.0 |
| Mustard | 0.8 | 2.6 | 2.5 | 4.3 |
| Chick pea | 0.7 | 2.5 | 3.2 | 4.3 |
| Chilli | 0.8 | 2.9 | 2.8 | 4.4 |
| Pumpkin | 0.8 | 2.7 | 3.3 | 4.2 |
| LSD (p=0.05) | 0.3 | 0.7 | 0.9 | 0.8 |

*barren land, no crops

In general, there were no differences in acid phosphatase activity under no crop condition of different crops land. However the results showed more influence of acid phosphatase in organic farming where 3-6 fold improvement in activities was noticed as compared to absolute control. The maximum improvement was obtained in wheat followed by chick pea. In general, 38.7% more acid phosphatase activity was found in organic farming than chemical farming ( Fig 7), where at least under two different crops (mustard and chilli) the activities decline than no input land.

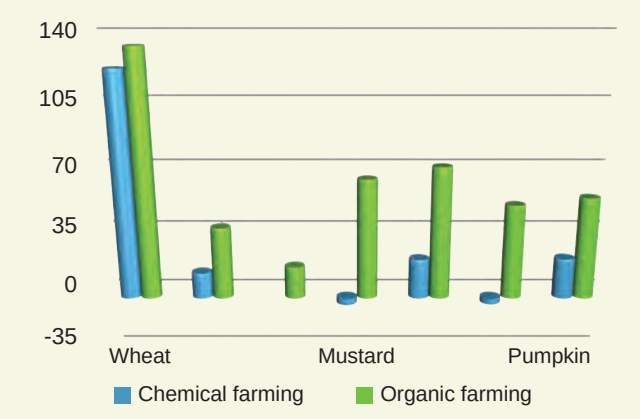



Fig 7. Changes in Acid phosphatase activity under chemical and organic farming

Except mustard, garlic and chilli (Fig 8) all other crops had higher acid phosphatase activity under chemical farming as compared to no input crops.

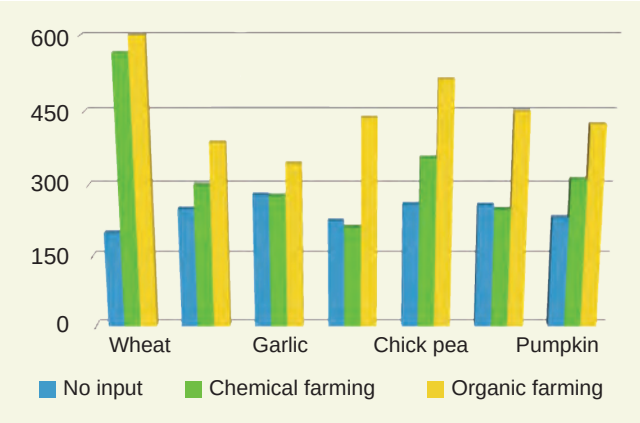



Fig 8. Status of Acid Phosphatase (EU x $10^{-3}$) under different crops and input practice

4. **Alkaline phosphatase:** Alkaline phosphatase is only contributing by microorganisms present in the soil. They are also equally effective in breaking down the C-O-P ester bond to bring phosphorus into phosphate form for plant availability. In general, organic farming results 25-100% improvement in alkaline phosphatase activity (Table 4) as compared to soil of absolute control. Potato crop growing areas showed more improvement in alkaline phosphatase activity followed by garlic.

**Table 4: Alkaline phosphatase (EU x $10^{-3}$) under different crops and farming practice.**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.6 | 1.0 | 0.9 | 1.1 |
| Potato | 0.7 | 1.1 | 0.9 | 1.4 |
| Garlic | 0.8 | 1.2 | 1.0 | 1.5 |
| Mustard | 1.0 | 1.0 | 1.0 | 1.4 |
| Chick pea | 0.9 | 0.9 | 0.8 | 1.2 |
| Chilli | 0.8 | 1.0 | 0.9 | 1.4 |
| Pumpkin | 0.9 | 1.3 | 1.1 | 1.5 |
| LSD (p=0.05) | 0.3 | 0.4 | 0.4 | 0.7 |

*barren land, no crops

The results (Fig 9) clearly showed that there was hardly any difference in alkaline phosphatase activity under no crop (control) land but upto18% decline in alkaline phosphatase activity over no input land was observed under chemical farming where 10-40% improvement in activity was noticed when farmers are practicing organic farming. The result showed tremendous contribution of organic farming on alkaline phosphatase activity. In general, the alkaline phosphatase activity under chemical farming was 73.4% less than organic farming irrespective of the crops cultivated.

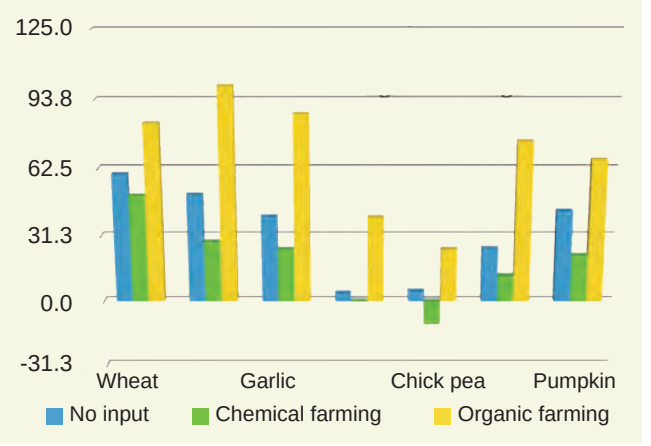



Fig 9. Status of alkaline phosphatase (EU x $10^{-3}$) under different crops and input practice

Except mustard, all other crops showed negative impact of alkaline phosphatase activities under chemical farming (Fig 10). The decline in alkaline phosphatase activity under potato was more (18.2%) followed by garlic (16.7%) and pumpkin (15.4%) while under chemical farming, which indicate an adverse effect on soil health due to chemical farming practice.

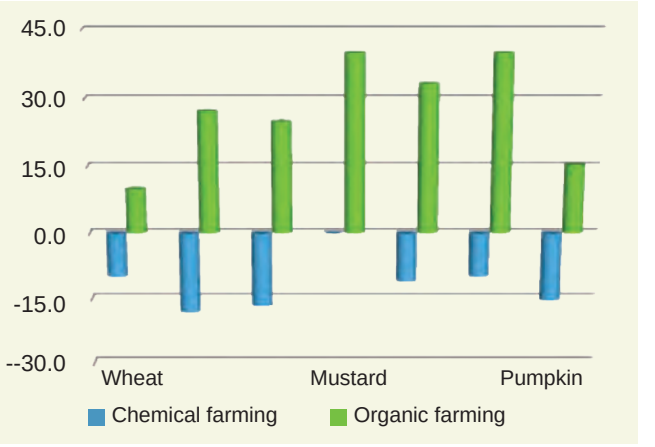



Fig 10. Changes in alkaline phosphatase activity under chemical and organic farming

## b) Biological parameters

1. **Fungi population:** The fungi population on different crops was increased over control soil between 6 and 36 fold (Table 5) when organic farming was practiced, which was much less under chemical farming (Fig 11). Except mustard, all other crops showed decline in fungal population under chemical farming than no input cultivation. The mustard field showed there was 59.7% improvement in the population under chemical farming which was enhanced to 14-47% further under organic farming.

**Table 5: Fungi (CFU x $10^3$/g) population under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 5.5 | 22 | 20.0 | 66.5 |
| Potato | 3.5 | 7 | 6.0 | 120.0 |
| Garlic | 7.0 | 20 | 19.5 | 94.0 |
| Mustard | 3.0 | 7.2 | 11.5 | 111.0 |
| Chick pea | 6.5 | 18.7 | 8.0 | 180.0 |
| Chilli | 8.5 | 20 | 14.0 | 160.0 |
| Pumpkin | 7.0 | 14.1 | 12.0 | 52.0 |
| LSD (p=0.05) | 4.2 | 7.3 | 6.5 | 11.1 |

*barren land, no crops

The more increase in fungal population was observed when mustard was grown in organic farming followed by potato. In general, 90% reduction in fungal population was observed under chemical farming as compared to organic farming growing plants although

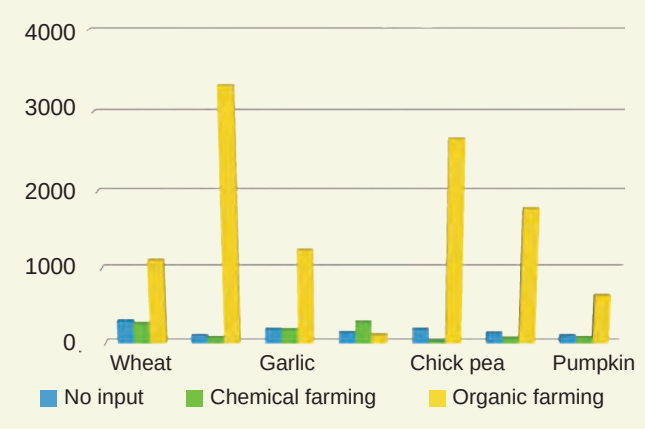



Fig 11. Status of Fungal population (CFU x $10^3$ $g^{-1}$) under different crops and input practice

hardly any difference in population was observed under control soil (Table 5). The most affected crops due to chemical farming seems to be potato and chick pea. It was noticed that plant contribution for fungal population development was much higher than soil contribution. The reduction in population due to chemical farming varies between 2.5-49.7% under different crops than no input agriculture. However, upto 16 fold improvement in fungal population was noticed due to organic farming practice when compared with no input crops (Fig 12).

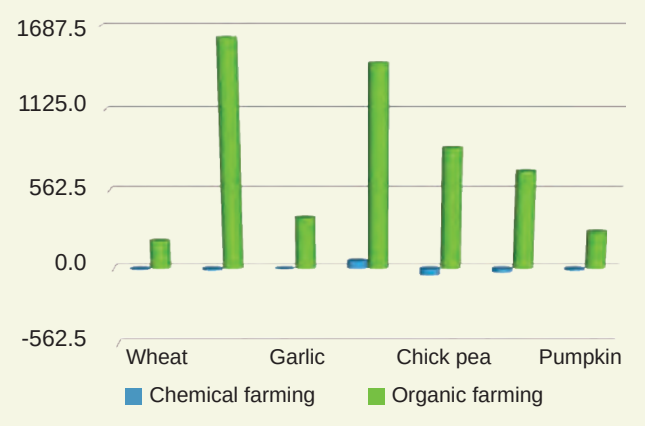



Fig 12. Changes in fungi population under chemical and organic farming

2. **Bacteria population:** Organic farming enhances bacteria population between 1.8- 6.2 fold under different crops (Table 6), which was 78% more build up than chemical farming. The higher build up was noticed under pumpkin followed by chilli and wheat. The plant contribution towards bacteria population was noticed between 42-66%. The reduction due to chemical farming over no input crop was between 5-33% which was more under mustard followed by garlic. In general, 50-241% increase in bacteria population was observed under organic farming over no input land (Fig 13).

**Table 6: Bacteria (CFUx$10^5$/g) population under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 2.5 | 4.4 | 4.0 | 15.0 |
| Potato | 3.0 | 8.4 | 8.0 | 12.0 |
| Garlic | 4.5 | 10.4 | 7.0 | 26.0 |
| Mustard | 3.5 | 6.0 | 4.0 | 10.0 |
| Chick pea | 5.0 | 9.3 | 7.0 | 14.0 |
| Chilli | 2.0 | 5.8 | 5.5 | 12.5 |
| Pumpkin | 4.0 | 8.8 | 8.0 | 29.0 |
| LSD (p=0.05) | 1.7 | 1.9 | 1.8 | 3.5 |

*barren land, no crops

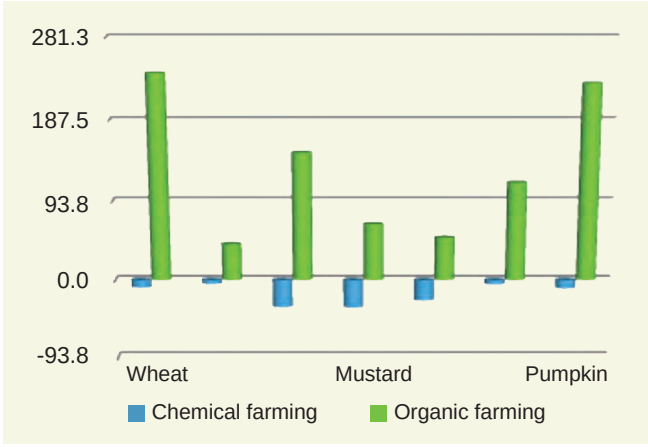



Fig 13. Changes in Bacteria population under chemical and organic farming

The adverse effect of chemical farming in bacterial population was obvious and it was more alarming especially under mustard, chick pea and garlic (Fig 14).

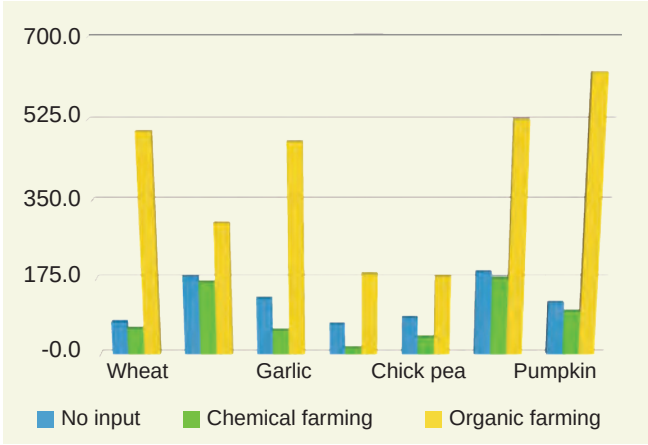



Fig 14. Status of bacterial population (CFU x $10^5$ $g^{-1}$) under different crops and input practice

The population build up under organic farming was found to be very effective under wheat followed by pumpkin among the seven crops compared.

**3. Actinomycetes population:** Organic farming build up 47-483% more actinomycetes population under seven crops tested (Table 7). The results showed more plant contribution under mustard (52.9%) to build up actinomycetes population.

**Table 7: Actinomycetes (CFU x $10^4$/g) population under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 34 | 43 | 39 | 50 |
| Potato | 39 | 45 | 40 | 67 |
| Garlic | 22 | 24 | 21 | 56 |
| Mustard | 17 | 26 | 24 | 85 |
| Chick pea | 18 | 23 | 22 | 105 |
| Chilli | 20 | 24 | 24 | 45 |
| Pumpkin | 25 | 30 | 28 | 70 |
| LSD (p=0.05) | 7.1 | 11.2 | 8.7 | 13.5 |

*barren land, no crops

However, garlic showed (9.1%) least plant contribution towards build up of the organisms. The reduction in activity due to chemical farming was between 0-13%, which was more under garlic and least under chilli (Fig 15).

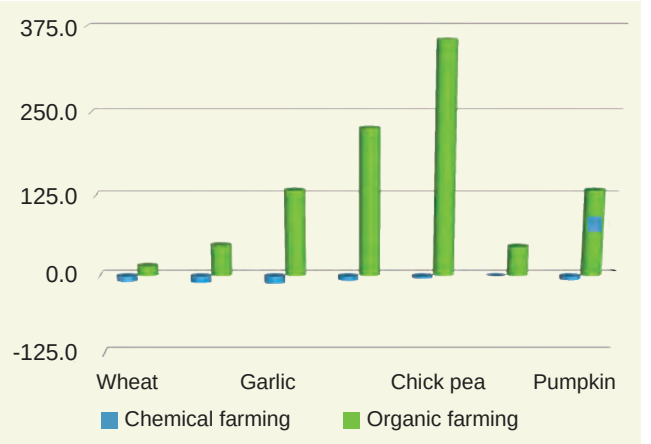



Fig 15. Changes in actinomycetes population under chemical and organic farming

The results showed 93% more build up of actinomycetes population under organic farming as compared to chemical farming (Fig 16). The maximum response to organic farming was observed under chick pea (356.5%) followed by mustard (226.9%). The least effect due to organic farming was observed under wheat (16.3%). It was very clear from the results that organic farming has definite edge over chemical farming and no input land to build up different organism's population under the rhizosphere of different crops grown under this region.

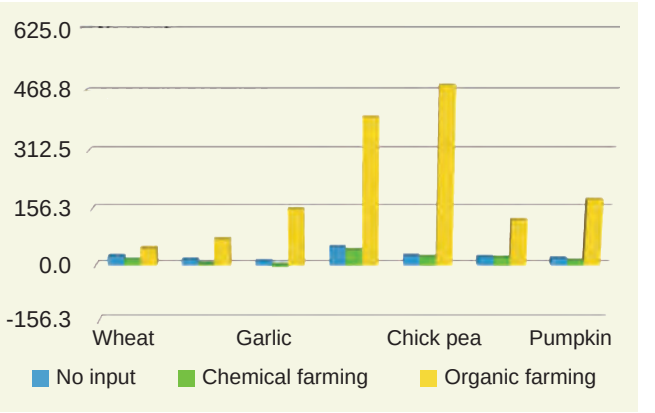



Fig 16. Status of actinomycetes population (CFU x $10^4$) under different crops and input practice

1. **Azotobacter population:** *Azotobacter* is a free living Nitrogen fixer, can fix nitrogen from the atmosphere without any outside help. In our study, their population was tremendously improved (upto 10 fold) due to organic farming practice under different crops (Table 8). It was more under mustard followed by potato and pum pkin. Although there was no significant difference in the barren land soil used for cultivation of seven crops tested.

**Table 8: *Azotobacter* (CFU x $10^2$/g) population under different crops and farming practice**

| Crop | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.5 | 1.4 | 1.5 | 3.0 |
| Potato | 0.4 | 1.0 | 1.0 | 4.0 |
| Garlic | 0.5 | 0.9 | 0.6 | 1.0 |
| Mustard | 0.5 | 0.5 | 0.1 | 5.5 |
| Chick pea | 0.3 | 0.4 | 0.1 | 2.0 |
| Chilli | 0.4 | 0.6 | 0.5 | 3.0 |
| Pumpkin | 0.5 | 0.8 | 0.7 | 5.0 |
| LSD (p=0.05) | 0.3 | 0.4 | 0.5 | 0.8 |

*Barren land, no crops

In most of the crops showed an adverse effect on *Azotobacter* population when chemical farming was practiced as compared to no input condition (Fig 17).

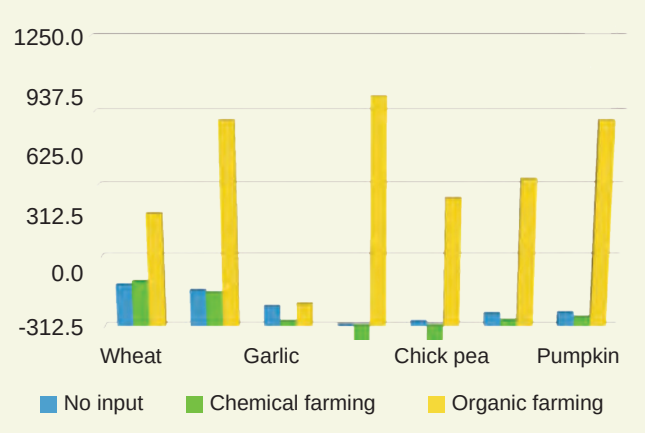



Fig 17. Status of Azotobacter population (CFU x $10^2$) under different crops and input practice

The result suggested that organic farming may booster nitrogen fixer population in the soil where in almost all the crops showed 1-10 fold increase in population except garlic where organic farming resulted only 11.1% improvement in Azotobacter population (Fig 18). Except under mustard all other crop shows significant plant contribution (25-64.3%) to build up Azotobacter population in the soil. The highest contribution was found under wheat followed by potato.

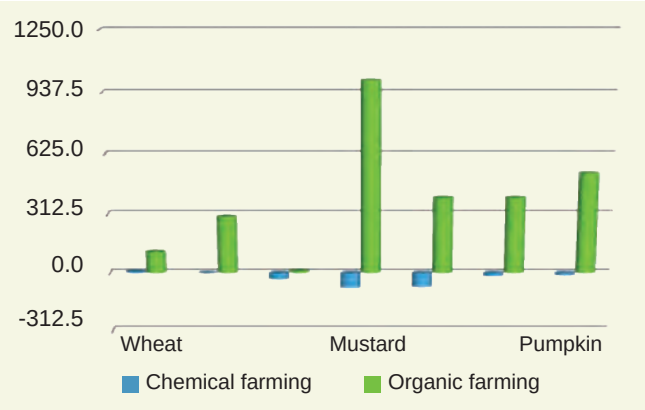



Fig 18. Changes in Azotobacter population under chemical and organic farming

2. **Nitrosomonas population:** Nitrosomonas helps in transformation of nitrogen in plant available form, which was much higher (75-354%) under organic farming as compared to the chemical farming (-24-102%). Organic farming under potato resulted more build up of population followed by wheat and pumpkin (Table 9). The results showed upto 54% influence on build up of nitrosomonas population under potato followed by garlic (33%) whereas wheat crop showed least influence on build up of nitrosomonas population. Under wheat there was 36% reduction in nitrosomonas population when chemical farming was practiced. The least reduction (-1.5%) was observed under potato followed by pumpkin (-9.4%). Organic farming enhance nitrosomonas population between 36 and 160% than no input land (Fig 19) which was more under wheat and least under chick pea.

**Table 9: Nitrosomonas (CFU $g^{-1}$) population under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 29 | 30 | 22 | 78 |
| Potato | 31 | 67 | 66 | 141 |
| Garlic | 28 | 42 | 35 | 60 |
| Mustard | 29 | 39 | 35 | 57 |
| Chick pea | 30 | 39 | 33 | 53 |
| Chilli | 28 | 35 | 24 | 49 |
| Pumpkin | 30 | 35 | 32 | 75 |
| LSD (p=0.05) | 5.1 | 7.3 | 6.9 | 13.0 |

*barren land, no crops

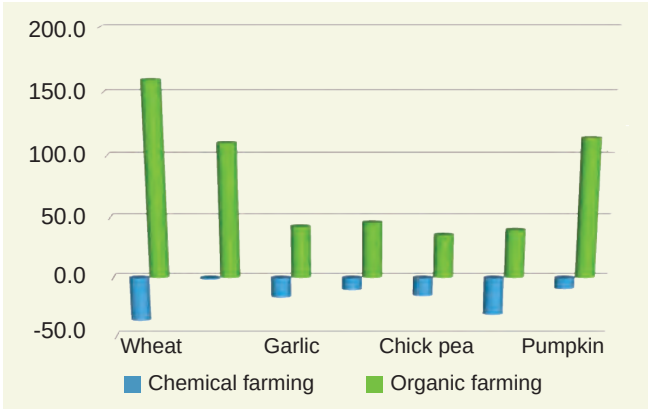



Fig 19. Changes in Nitrosomonas population under chemical and organic farming

The results (Fig 20) suggested enhancing nitrifying bacterial population; organic farming has a great role.

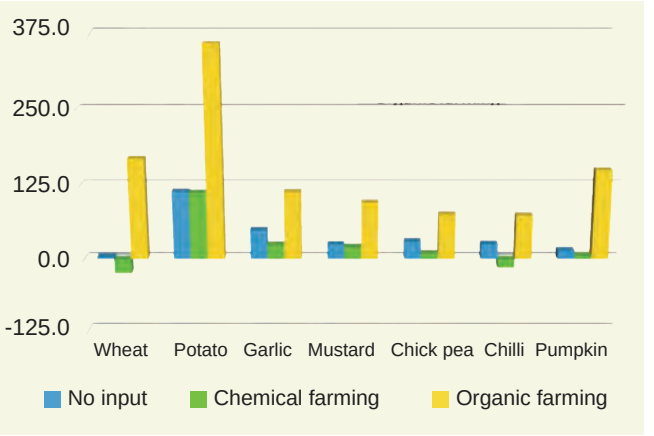



Fig 20. Status of nitrosomonas population (CFU $g^{-1}$) under different crops and input practice

## C. Physio-chemical parameters

1. **Organic matter:** The build up of organic matter was much higher under different crops when organic farming was continuously practiced. The more build up was observed under mustard and garlic (Table 10). Plant contributed more on organic matter build up under wheat (33.3%), garlic (28.6%) and chick pea( 23.1%) while least contribution was noticed under chilli 5.2% and potato 7.2%. In general, chemical farming resulted in reduction of organic matter build up by -14% under different crops, than no input land. The results showed 29-99% build up of organic matter over no input land due to organic farming practiced for a long time under different crops (Fig 21).

**Table 10: Organic matter (%) content under different crops and farming practice.**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.80 | 1.20 | 1.14 | 1.67 |
| Potato | 0.80 | 0.86 | 0.74 | 1.27 |
| Garlic | 0.85 | 1.19 | 1.17 | 2.21 |
| Mustard | 1.12 | 1.35 | 1.34 | 2.68 |
| Chick pea | 0.90 | 1.17 | 1.12 | 1.47 |
| Chilli | 0.92 | 0.97 | 0.95 | 1.62 |
| Pumpkin | 0.85 | 0.93 | 0.85 | 1.29 |
| LSD (p=0.05) | 0.11 | 0.18 | 0.15 | 0.21 |

*barren land, no crops

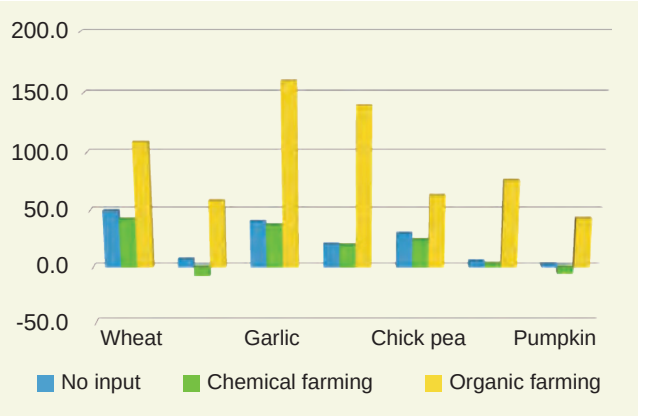



Fig 21. Status of Organic matter (%) under different crops and input practice

2. **pH:** There was slight decline in soil pH (1-5%) due to organic farming than barren land under different crops (Table 11). The more reduction was observed under potato and garlic where 0.4 unit reduction in pH was noticed. The reduction in pH due to crop cultivation (no input condition) was noticed between 2-4.4% (Fig 22).

**Table 11: pH of different crops and farming practice**

| Crop | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 7.1 | 7 | 7.3 | 7.0 |
| Potato | 7.2 | 6.9 | 7.2 | 6.8 |
| Garlic | 7.3 | 7 | 7.6 | 6.9 |
| Mustard | 7.1 | 6.9 | 7.2 | 6.8 |
| Chick pea | 6.9 | 6.8 | 6.8 | 6.7 |
| Chilli | 7.2 | 7.1 | 7.3 | 7.0 |
| Pumpkin | 7.0 | 6.9 | 7.1 | 6.9 |
| LSD (p=0.05) | 0.1 | 0.1 | 0.1 | 0.1 |

*barren land, no crops

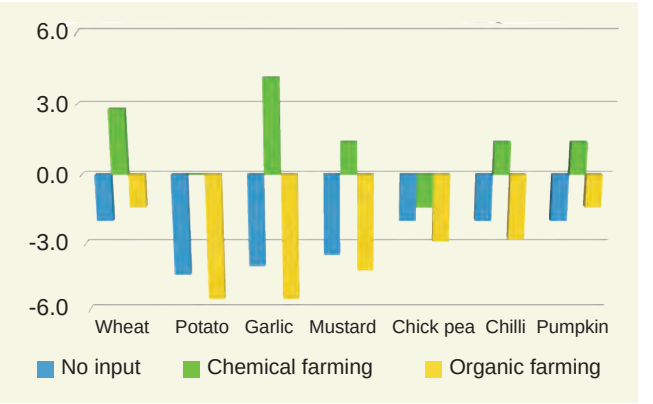



Fig 22. Status of pH under different crops and input practice

In general, -1.4 to 4.1 changes in pH was noticed under chemical farming while slight improvement in pH was also noticed (upto 0.3 units) due to practice of organic farming. The results suggested pH does not change much both under chemical and organic farming practice.

3. **EC:** There was hardly any major change in electrical conductivity of soil due to chemical or organic farming under different crops tested (Table 12). All crops under chemical farming resulted decline in EC between 5 and 52% (Fig 23), which was more under garlic followed by mustard. The reduction of EC upto 15% was also noticed when plants were grown under no input conditions where reduction was more under wheat and mustard. In general, there was slight increase in EC under potato and garlic where organic farming was practiced.

**Table 12: Electrical conductivity (dS/m) under different crops and farming practice**

| Crop | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.20 | 0.17 | 0.16 | 0.11 |
| Potato | 0.18 | 0.17 | 0.15 | 0.27 |
| Garlic | 0.21 | 0.21 | 0.10 | 0.22 |
| Mustard | 0.13 | 0.11 | 0.08 | 0.07 |
| Chick pea | 0.12 | 0.11 | 0.08 | 0.09 |
| Chilli | 0.18 | 0.17 | 0.17 | 0.16 |
| Pumpkin | 0.19 | 0.17 | 0.13 | 0.11 |
| LSD (p=0.05) | 0.3 | 0.2 | 0.4 | 0.4 |

*barren land, no crops

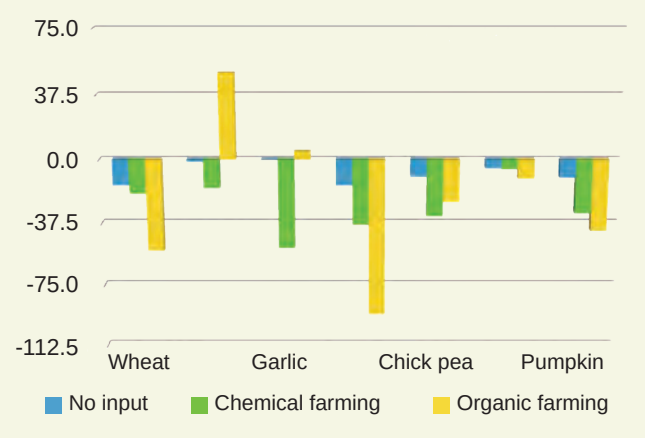



Fig 23. Status of EC (dS $m^{-1}$) under different crops and input practice

4. **Total Nitrogen:** The total N content in soil under organic farming of seven different crops tested was varies between 44-147% (Table 13), which was more under garlic followed by mustard. Except potato and pumpkin, there was no change in total N under chemical farming when compared with no input soil. It decline in total N content between 7 and 22% was noticed when mustard and potato was grown under chemical input.

**Table 13: Percentage total Nitrogen (N) under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.08 | 0.11 | 0.11 | 0.16 |
| Potato | 0.08 | 0.09 | 0.07 | 0.13 |
| Garlic | 0.09 | 0.11 | 0.11 | 0.22 |
| Mustard | 0.11 | 0.14 | 0.13 | 0.26 |
| Chick pea | 0.09 | 0.11 | 0.11 | 0.14 |
| Chilli | 0.09 | 0.10 | 0.10 | 0.16 |
| Pumpkin | 0.09 | 0.09 | 0.09 | 0.13 |
| LSD (p=0.05) | 0.03 | 0.02 | 0.04 | 0.05 |

*barren land, no crops

The present result suggested that to build up of N status in the soil, organic farming has major role than chemical farming or no input soil (Fig 24). In general, 21-100% build up of N content was observed under different crops were regularly organic farming was practiced. The more build up (100%) over no input land was noticed under garlic followed by mustard (85.7%) and chilli (60%).

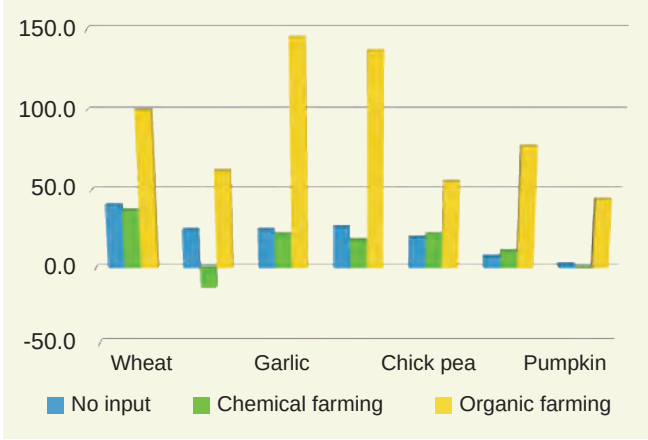



Fig 24. Status of Total N (%) under different crops and input practice

5. **Available P:** Except for two crops (mustard and chick pea) organic farming enhances available P content upto 63% over no input soil. In general, very poor performance of plant contribution was noticed (5-17%) to build up available P under different crops. An erratic result was observed on available P status under chemical farming due to non uniformity of application under different farmers field condition but more available P build up under chemical farming was notice under potato followed by chilli while chick pea showed no change in available P status both under chemical and organic farming (Table 14).

**Table 14: Available P (mg/kg) under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 21.1 | 24.3 | 28.2 | 33.6 |
| Potato | 25.5 | 30 | 71.8 | 43.7 |
| Garlic | 29.2 | 35.1 | 43.9 | 44.2 |
| Mustard | 28.7 | 34.6 | 46.1 | 30.0 |
| Chick pea | 24.0 | 25.4 | 25.3 | 24.9 |
| Chilli | 26.0 | 28.7 | 64.3 | 46.9 |
| Pumpkin | 27.2 | 31.3 | 35.0 | 38.7 |
| LSD (p=0.05) | 1.7 | 2.1 | 3.5 | 3.2 |

*barren land, no crop

In general, sharp improvement of available P status was observed both under chemical and organic farming when compared with no input crop. The effect was more under potato and chilli (Fig 25).

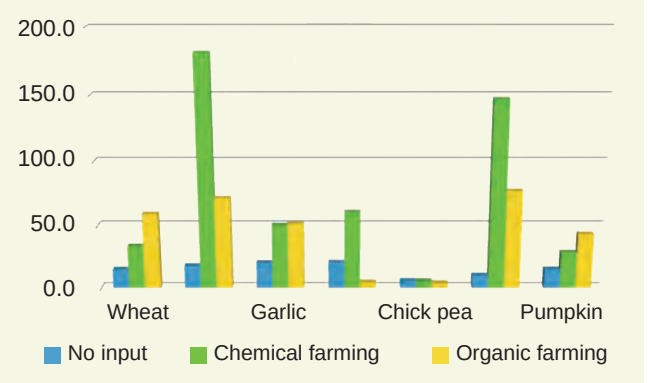



Fig 25. Status of available P (mg $kg^{-1}$) under different crops and input practice

6. **Available K:** Although negative impact on available K status due to chemical farming, in general, was noticed but organic farming enhances available K status under all the crops tested crops between 14-84%. The more positive effect on organic farming over no input soil was notice under garlic (84.4%) followed by chilli (20.5%). Except potato and pumpkin, all other crops growing in chemical farming showed negative build up of available K which was maximum under garlic (-22.2%). The results (Table 15) also showed least plant contribution to build up available K status in the soil. The changes in available K status over absolute control was presented as Fig 26. The results clearly showed garlic builds more available K status in the soil when organic farming was practiced.

**Table 15: Available K (mg/kg) under different crops and farming practice**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 124.3 | 115.6 | 106.6 | 137.3 |
| Potato | 110.9 | 120.3 | 141.7 | 141.4 |
| Garlic | 108.8 | 95 | 73.9 | 175.2 |
| Mustard | 112.0 | 118.7 | 117.7 | 135.5 |
| Chick pea | 110.0 | 115 | 114.0 | 132.2 |
| Chilli | 108.0 | 102.6 | 100.5 | 123.6 |
| Pumpkin | 105.0 | 120.8 | 142.3 | 140.5 |
| LSD (p=0.05) | | | | |

*barren land, no crops

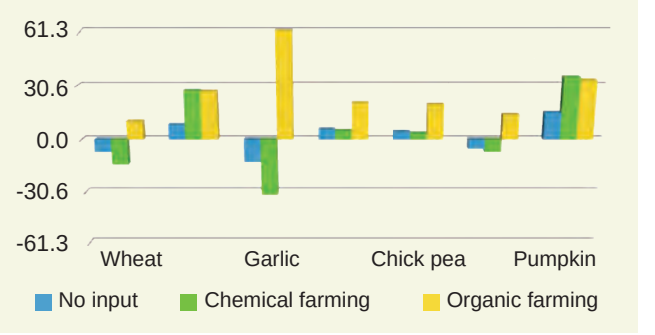



Fig 26. Status of available K (mg $kg^{-1}$) under different crops and input practice

7. **Zinc content:** Zn plays an important role in different plant metabolism processes like development of cell wall, respiration, photosynthesis, enzyme activity and other biochemical functions. The available Zn content under different crops grown under various farming

system was presented as Table 16. The results clearly showed that there was variation in available Zn under different crops, which was more under pumpkin and least under chilli. No input soil, as compared to no crop land, resulted declining in Zn concentration between 2.9 and 6.5%. That was maximum under potato and minimum under gram (Fig 27). Chemical farming was influencing Zn deficiency under different crops by reducing available Zn between 15.9 and 37.8% while organic farming helps to restore the Zn availability in soil. The increase in availability varies between 1.3 and 14.3% under different crops where at least five years organic farming was practised. The build up was more under mustard and pumpkin while less under wheat and potato.

**Table 16: Available Zn content (mg $kg^{-1}$) under different crops**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.76 | 0.73 | 0.61 | 0.77 |
| Potato | 0.77 | 0.72 | 0.53 | 0.78 |
| Garlic | 0.66 | 0.64 | 0.41 | 0.73 |
| Mustard | 0.84 | 0.80 | 0.66 | 0.96 |
| Chick pea | 1.03 | 1.00 | 0.85 | 1.06 |
| Chilli | 0.69 | 0.66 | 0.58 | 0.75 |
| Pumpkin | 1.29 | 1.21 | 0.96 | 1.41 |
| LSD (p=0.05) | 0.18 | 0.26 | 0.19 | 0.25 |

*barren land, no crops

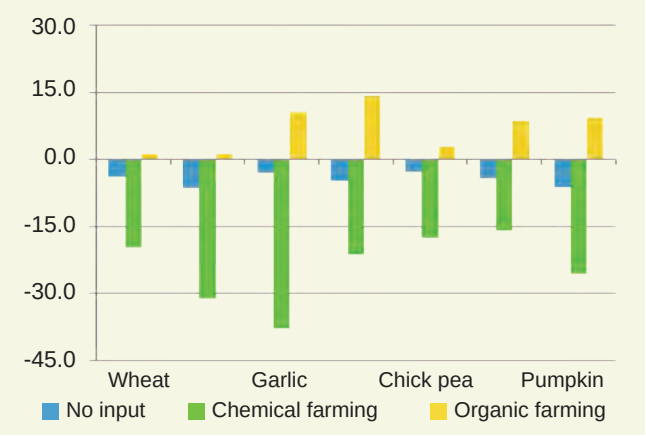



Fig 27. Available Zn status under different crops and farming system

8. **Copper content:** Cu has a role in controlling plant pathogens, which ultimately influence the yield of crops. In general, Cu content varies between 0.32-0.85 mg kg-1 under different soils of Navdanya farm areas (Table 17). Under no input soils there was declining in concentration between 1.4 to 13.2%, which was more under mustard and least under pumpkin (Fig 28). Chemical farming reducing Cu concentration farther between 4.2 and 21.3%, that can be restored by last five years continuous organic farming where improvement in Cu concentration was noticed upto 9.4%

**Table 17: Available Cu (mg $kg^{-1}$) under different crops**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 0.37 | 0.36 | 0.35 | 0.37 |
| Potato | 0.32 | 0.29 | 0.28 | 0.35 |
| Garlic | 0.59 | 0.57 | 0.55 | 0.60 |
| Mustard | 0.38 | 0.33 | 0.32 | 0.38 |
| Chick pea | 0.61 | 0.58 | 0.48 | 0.62 |
| Chilli | 0.85 | 0.81 | 0.71 | 0.86 |
| Pumpkin | 0.71 | 0.70 | 0.68 | 0.73 |
| LSD (p=0.05) | 0.19 | 0.17 | 0.15 | 0.21 |

*barren land, no crops

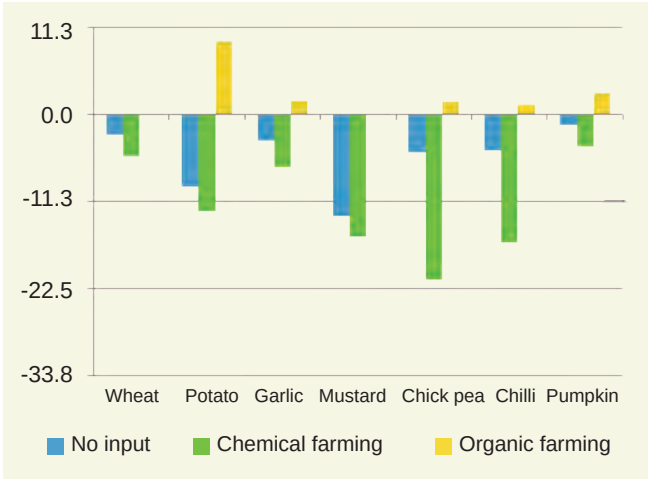



Fig 28. Available Cu status under different crops and farming systems

When compared with no input soil, there was an improvement between 3-21% of available Cu under different crops due to organic farming. On the other hand, chemical farming reduces the Cu availability in the soil between 3-12%. The results clearly showed that the ill effect of chemical farming can be nullified by the practice of organic farming.

9. **Manganese content:** Manganese has a great role in crop physiology. It also supports the movement of iron in the plant and it helps in the formation of chlorophyll. Manganese influences auxin levels in plants and high concentration of manganese favour the breakdown of indole acetic acid (IAA). The available Mn content under barren land of crops growing areas was varied between 2.16- 4.66 mg $kg^{-1}$ (Table 18).

**Table 18: Available Mn (mg $kg^{-1}$) content under different crops**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 2.16 | 2.01 | 1.78 | 2.26 |
| Potato | 4.07 | 3.98 | 3.48 | 4.66 |
| Garlic | 4.57 | 4.50 | 4.38 | 4.76 |
| Mustard | 2.26 | 2.11 | 2.02 | 2.32 |
| Gram | 4.66 | 4.21 | 4.05 | 4.76 |
| Chilli | 3.81 | 3.76 | 3.65 | 3.85 |
| Pumpkin | 2.39 | 2.30 | 2.11 | 2.42 |
| LSD (p=0.05) | 0.83 | 0.72 | 0.98 | 0.77 |

*barren land, no crops

Due to uptake by different crops under no input treatment, the Mn content was declining between 1.3 and 9.7% with maximum under gram and minimum under chilli (Fig 29). Chemical farming introduce further decline in Mn concentration from 4.2% to 17.6% over control. There was 1 to 14.5% improvement in available Mn concentration due to organic farming practice under different crops, which was more under potato.

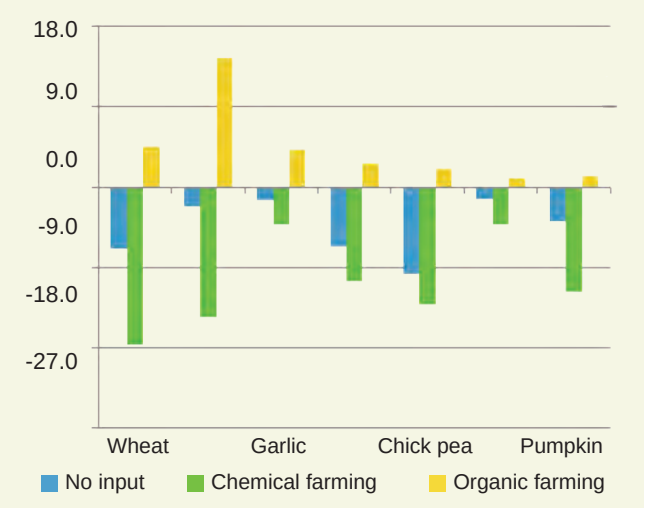



Fig 29. Available Mn status under different crops and farming systems

10. **Iron content:** Iron helps both as a structural component and as a cofactor for enzymatic reactions. The available iron content under barren land in Navdanya farming areas was 4.21-8.94 $mgkg^{-1}$(Table 20).

**Table 20: Available Fe (mg $kg^{-1}$) content under different crops**

| Crops | Control* | No input | Chemical farming | Organic farming |
|---|---|---|---|---|
| Wheat | 8.94 | 8.10 | 7.87 | 8.95 |
| Potato | 7.98 | 7.77 | 7.20 | 8.00 |
| Garlic | 7.85 | 7.80 | 7.33 | 7.90 |
| Mustard | 4.21 | 4.00 | 3.91 | 4.20 |
| Chick pea | 6.85 | 6.69 | 6.55 | 6.91 |
| Chilli | 7.99 | 7.82 | 7.49 | 8.01 |
| Pumpkin | 5.73 | 5.66 | 5.12 | 5.80 |
| LSD (p=0.05) | 1.01 | 1.23 | 0.98 | 1.19 |

*barren land, no crops

The available Fe content was reduced between 0.6-9.4% where crops were growing without any input but the concentration was decreased between 4.3 and 12.0% due to practice of chemical farming for a longer period. However, continuous organic farming can maintain the available Fe concentration (Fig 30) in the soil under different crops. In general, the results clearly showed that organic farming has a great role to maintain micronutrient concentration in the soil.

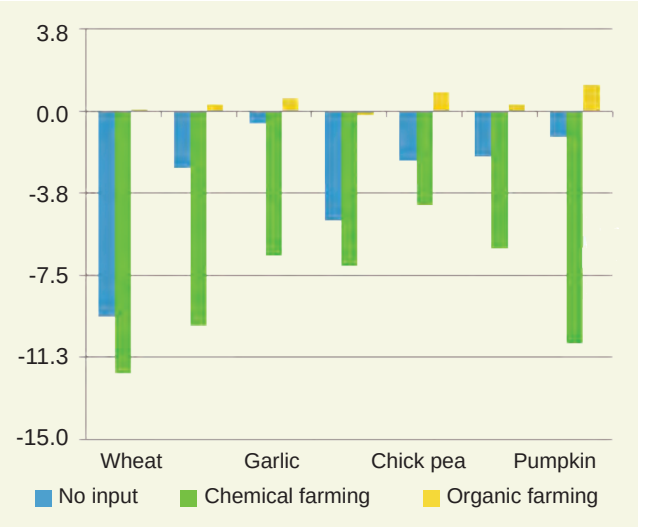



Fig 30. Available Fe status under different crops and farming systems

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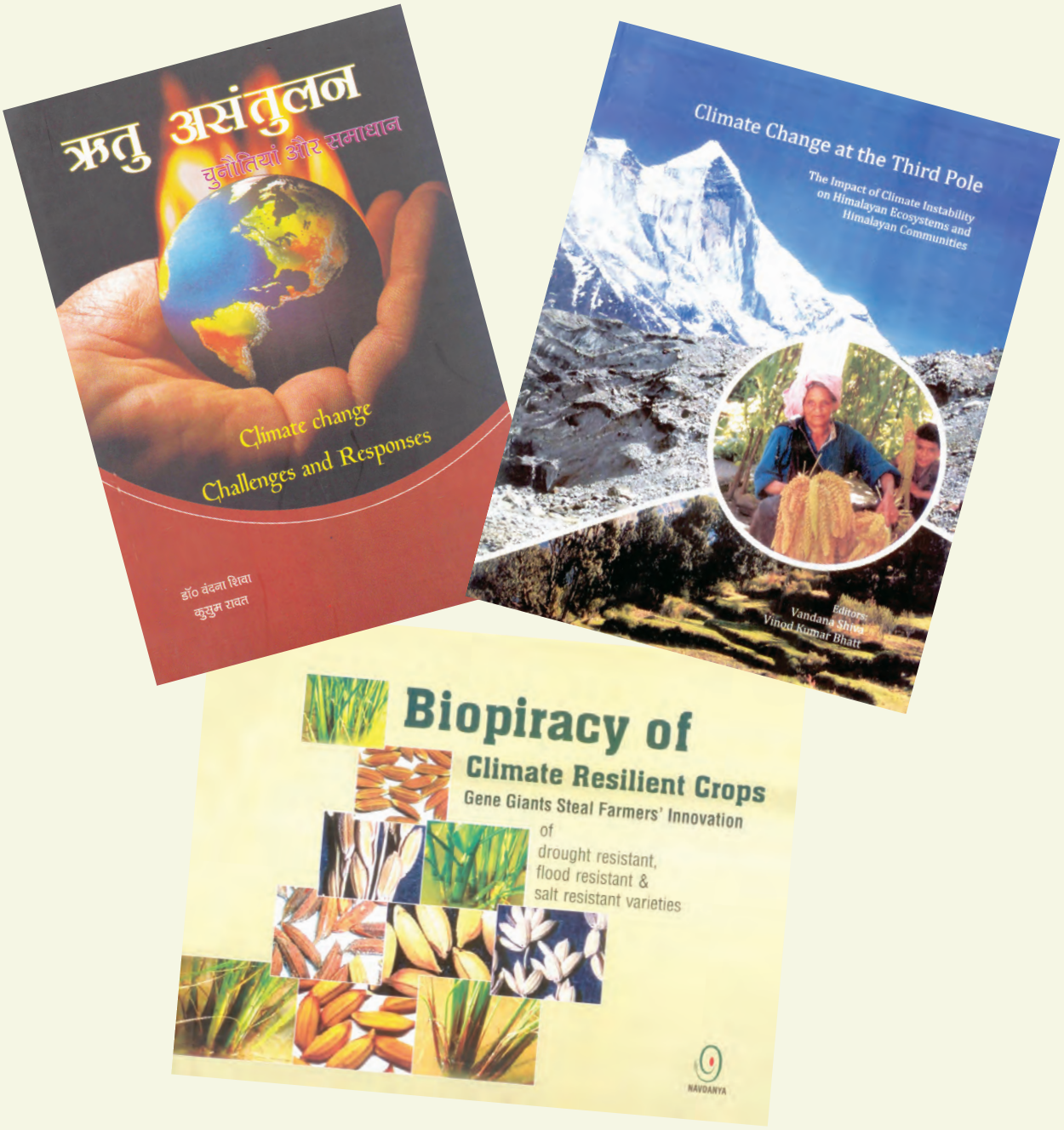


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