or sterility, nor do they include suicide poisonings.

— Some pesticides, because of their water insolubility, tend to accumulate in the fatty tissues of plants and animals as they move through the "food chain", posing danger to birds and man who are at the top of the food-chain. DDD was applied in Clear Lake, California at levels of 14 parts per billion to control gnats. Although this treatment relieved the lakeside of its gnat problem, the compound ultimately became part of the aquatic food chain and was concentrated to levels 80,000 times greater than the original –a concentration strong enough to kill fish-eating birds.

— Pesticides are persistent in nature and stay for years. Though DDT was banned in the USA in 1972, it is still found in vegetables and fruits sold in American supermarkets, as well as in mother's milk, in much larger concentration than what is tolerable.

"Many or most of the countries subsidising the use of water, chemicals in agriculture and energy - are thus encouraging overuse, waste and pollution."

— World Resources Institute, Washington D. C. (1989)

Dr. M. S. Swaminathan, the world renowned agricultural scientist had cautioned, way back in 1968, when the green revolution was just taking shape :

"Intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and the other diseases, through the toxic residues being present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into a traditional agricultural system and without first building up a proper scientific and training base to sustain it may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity."

3.2 What Is Sustainable Agriculture ?

Worldwide there is an increasing awareness about alternative/natural/biological/organic/sustainable agricultural practices in view of energy shortages, food safety and environmental concerns, arising out of conventional (chemical) farming. Whatever be the name, this alternative system avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, this system relies upon:

— efficient recycling of crop residues, animal manures, green manures, off-farm organic wastes - reducing their pollution potential, simultaneously
— minimum mechanical cultivation, to maintain soil productivity and tilth
— mineral-bearing rocks to supply plant nutrients
— increase in the pest-resistance through balanced nutrition of the plants
— biological pest control
— crop rotation
— mixed cropping.

Sustainable agriculture is one in which the goal is permanence achieved through the utilisation of renewable resources. Basic elements of sustainable agriculture are conservation of energy, soil and water.

That is - for a farm to be sustainable it must produce adequate amounts of high quality food, protect its resources and be both environmentally safe and profitable. Essential to achievement of conservation are agricultural practices that are directed towards renewability and non-pollution of resources. This does not mean simply a return to primitive agriculture, with the complete elimination of agrochemicals, but use of efficient mechanisms of soil biotechnology.

3.3 Sustainable Agriculture In The USA :

Large number of American farmers are questioning the environmental, economic and social impacts of conventional chemical agriculture. Consequently, many of them are seeking alternative practices that would make agriculture more sustainable. According to the U. S. Department of Agriculture estimate, between 90,000 to 1,00,000 farmers - about 5% of nation's total - are practising sustainable agriculture today.

Farmers, who practise soil conservation and reduce their dependence on fertilizers and pesticides, generally report that their production costs

are lower than those of nearby conventional farms. Sometimes the yields from sustainable farms are somewhat lower than those from conventional farms, but they are frequently offset by lower production costs, which leads to equal or greater net returns.

The USDA commissioned a study in 1979 to assess the extent of organic farming in the USA, as well as the technology behind the farming and its economic and ecological impact. The study, "Report and Recommendations on Organic Farming", published in 1980 was based heavily on case studies of 69 organic farms in 23 states.

The USDA report concluded that organic farming is energy-efficient, environmentally sound, productive and stable and tends toward long-term sustainability. Since the report was published, it has stimulated interest, both in the USA and outside, in sustainable agriculture. Its recommendations provided the basis for the alternative agriculture initiative passed by the U.S. Congress in the Food Security Act of 1985, which calls for research and education on sustainable farming systems.

The sustainable agriculture movement received a further boost in September1989 when the Board on Agriculture of National Research Council of the USA released another study, "Alternative Agriculture". The report is perhaps the most important confirmation of the success

of farms that rely on biological resources and their beneficial interactions instead of chemicals. It found that well-managed farms growing diverse crops with little or no chemicals are as productive and often more profitable than conventional farms. It also asserted that "wider adoption of proven alternative systems would result in even greater economic benefits to farmers and environmental gains for the nation."

3.4 Towards Sustainable Agriculture :

There are numerous sustainable farms around the world. They have consistently produced yields comparable to chemical agriculture, year after year. Their net returns are higher, by 15-20 percent, with reduced inputs.

However, the change-over from chemical to sustainable agriculture is difficult. Farmers have to forego yields for 3-5 years, till the soil productivity is built up by recycling of organic matter. Few farmers can bear this loss. The planners, too, cannot accept lesser food production to feed the growing population.

Hence, the biggest challenge we have at present is : how to change the farming system without any loss of yield ?

3.5 Quick Change-over To Sustainable Agriculture :

It is possible to effect a quick change-over to sustainable agriculture by harnessing vermiculture biotechnology to the soil.

Good earthworm population is a measure of soil productivity. Hence, establishing an earthworm population of 0.2-1.0 million per hectare within a short period of three months is the key to a quick change-over without loss of yield. Different consideration in this regard are :

1. Worms should be of deep-burrowing type (endogees), those possessing digging muscles, enabling them protect from harsh field conditions.
2. Burrowing worms show high mortality when shifted from one place to another, due to environmental shock. Hence, they should be hatched in the new environment, from vermicastings containing worm cocoons and beneficial soil microflora.
3. The package should be simple and cost-effective to the farmers.

Bhawalkar Earthworm Research Institute (BERI), Pune, India, has developed a cost effective, practical package for a quick changeover to sustainable agriculture without any loss of yield. Farmers from diverse agro-climatic regions have successfully adopted this package on diverse crops.

The package consists of :

— Applying first a layer of vermicastings at the rate of 5 tons per ha (costing, about Rs. 2,500 to 3,000 per ton at present).

Vermicastings are applied only in areas where sufficient moisture is present, like basins below trees, below drippers or in furrows (in case of crops grown in ridge-and-furrow beds).

— Feeding earthworms with fresh animal dung, in 20 mm layer, below the mulch, if possible.

— Watering every 15-20 days, as the mulch reduces moisture loss from the soil.

— Periodic application of dung & mulch as they are consumed.

Organic materials like weeds (uprooted when fully grown), agricultural residues, city wastes or food-processing wastes can be used for mulching.

Worms hatch out within a month. They start processing the organic mulch and produce vermicastings, in situ. No further doses are, ideally, required to be added, if the above mentioned procedure is followed religiously. This makes the package cost-effective to the farmers.

3.6 Soil Biotechnology (Figure 7) :

— Worms build up density of beneficial bacteria and actinomycetes, 1,000 times inside their guts, by providing optimum conditions of temperature, moisture, aeration and pH.

— Worms also produce several enzymes which split complex polymers, in wastes, into simple molecules, which are further utilised by the soil micro-organisms.

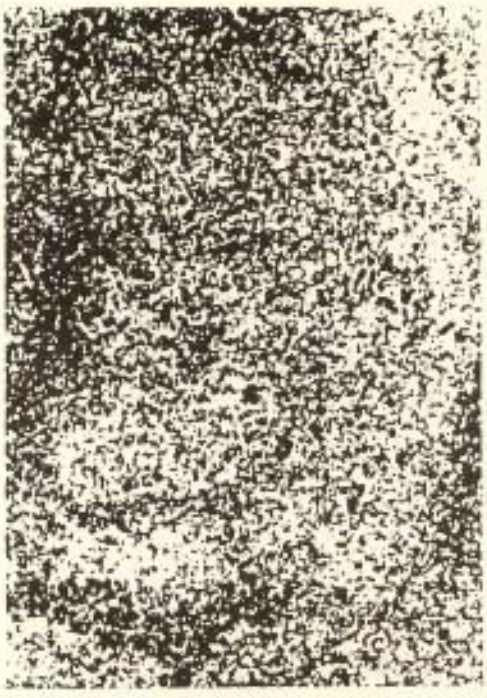
— Worms assimilate some of the micro-organisms as their food. Hence, more the microbial biomass in the soil, more will be the worm biomass, which can be supported by the soil.

Though a farmer cannot see the microbial activity by the naked eyes, he can see the worm activity. Higher the worm activity, better the microbial action, leading to soil productivity.

— Worms enrich the soil with oxygen, encouraging aerobic micro-organisms. These are mostly useful micro-organisms which perform several important functions like :

- N-fixation
- Nitrification
- Production of enzymes, antibiotics, growth-hormones, etc.

THE EFFECT OF EARTHWORMS ON THE SOIL



Soil heavy, packed, almost impervious to water. Cakes under hot sun; hard to cultivate; Restricts plant and root growth. **No earthworms.**

With earthworms; soil is granulated, light, crumbly; absorbs water; gives plant life & chance to grow normally.

Figure 7

— Pathogens are destroyed due to proliferation of these beneficial soil micro-organisms.
— Other troublesome organisms, like nematodes, are reduced by worm action.
— Normal microbial biomass, about 1 ton per ha, acting in the top 30 cm, is boosted by the worms to 10 tons per ha, acting in 3 m depth of the soil. Worm biomass corresponding to this microbial biomass will be about 1 ton per ha. Hence a farmer can have a work-force of 11 tons of biomass, per ha, working quietly underground, day and night. This can be compared to the 1 ton biomass, of two bulls, doing conventional cultivation, above ground.

3.7 Biotechnological Farming Practices :

3.7.1 Cultivation :

Mechanical cultivation, normally reaching a depth of 30 cm only, is replaced by cultivation (upto 3 m) by soil organisms and plant roots.

3.7.2 Weeding :

As long as weeds do not compete with the main crop, for sunlight, they are allowed to grow. They are then periodically cut and used for mulching (feed for the soil organisms). No herbicides are used.

3.7.3 Fertilizers :

Fertilization is through soil biotechnological processes. Diverse organic wastes are utilized as raw materials to produce balanced fertilizers for the plants.

3.7.4 Pesticides :

Plants develop pest-resistance by balanced nutrition provided by the soil organisms. Biological control of pests and the use of environment-friendly herbal pesticides (such as neem-extract) are also encouraged.

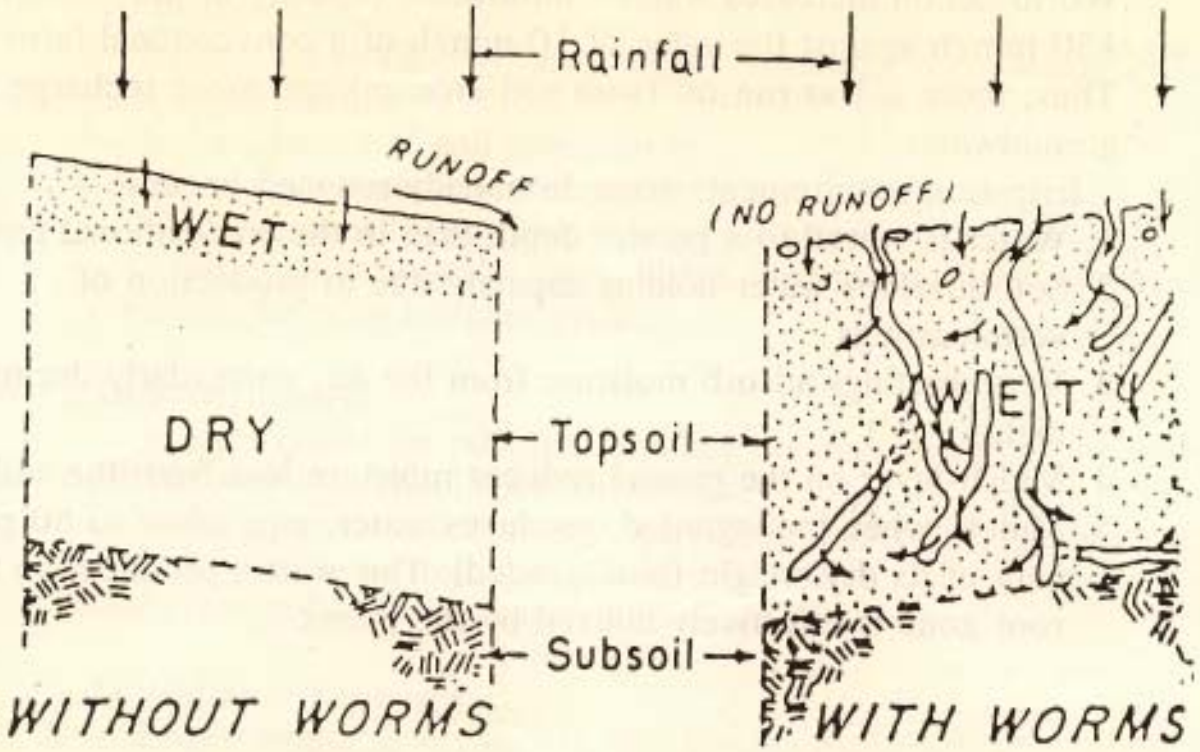


Figure 8

3.7.5 Irrigation (Figure 8) :

Worm-action increases water - infiltration capacity of the soil upto 130 mm/h against the value of 10 mm/h of a conventional farm soil. Thus, there is less run-off (with soil-erosion) and more recharge of groundwater.

Irrigation requirements are substantially reduced because –

1. Water is stored to a greater depth than in the conventional farm.
2. Soil develops water-holding capacity due to production of vermicastings.
3. Vermicastings adsorb moisture from the air, particularly during the night.
4. Mulch-layer on the ground reduces moisture loss from the soil.
5. Mulch, when biodegraded, produces water, equivalent to 60 per cent of its dry weight (biodegraded). This water, produced in the root-zone is effectively utilized by the plants.

3.8 Benefits Of Sustainable Agriculture :

To Farmers :

— Less reliance on purchased inputs, resulting in considerably low cost of production
— Enhancement of soil productivity
— More yield with lesser irrigation
— No tension of losing the crop to pest-attack
— A produce with better taste, lustre, keeping qualities, lower toxic residues, fetching a higher price

To Environment :

— Wastes create no pollution, as they become valuable raw materials for the soil biotechnological processes.
— More groundwater recharge and lesser depletion of groundwater
— Soil salinization reduced, lesser soil erosion
— Lesser pollution from agro-chemicals

To National Economy :

— Lesser imports, saving valuable foreign exchange
— More export of agricultural produce with lower pesticide residues

4. Vermiculture Biotechnology For Wasteland Development

A land which remains barren is termed as a wasteland. Two-third of the potentially productive land (266 Mha), of the total land (304 Mha) of India is subject to some form of degradation. 90 Mha is officially declared as wasteland by the National Wasteland Board.

Increasing wasteland formation, coupled with the population growth has resulted in reduced per capita land availability for cultivation :

Year	Per Capita Land For Cultivation
1951	0.48 ha
1981	0.20 ha
2000	0.14 ha

4.1 Causes Of Wasteland Formation :

— Neglected agriculture on marginal and poor soils
— Shifting cultivation on hill-slopes
— Lack of soil and moisture-conservation practices in agriculture
— Destruction of ecology by mining, electrification, construction and other industrial projects
— Excessive irrigation, with poor drainage and overuse of chemicals
— Overgrazing by animals
— Increased demand for forest products, leading to deforestation
— Neglect of commons (village and government owned lands)

Vermiculture biotechnology has a potential of correcting some of these causes and arresting the speed of wasteland formation.

4.2 Types Of Wastelands And Their Development :

4.2.1 Shallow Soils — can be developed by :

— plantation of trees along contours
— application of 2 kg vermicastings per pit
— application of 100 mm mulch over the layer of vermicastings, preferably after applying 20 mm layer of dung
— watering, as needed

— subsequent mulching with grass/weeds cut from the interspaces between the trees.

4.2.2 Sand Dunes — can be brought under vegetation of xerophytes by a procedure as detailed above.

4.2.3 Saline And Alkali Soils — can be effectively improved by planting salt-tolerant trees and adopting the procedure given in 4.2.1 with application of 5 kg vermicastings per pit.

4.2.4 Drought Affected Areas — should brought under tree plantation suitable to dry-farming, with an application of vermicastings and mulch.

5. CASE STUDIES

5.1 CASE 1 : SUCCESSFUL SUGARCANE FARMER

Krishnat L. Phule
Aasu (Phone : 39), Tal. Phaltan
Dist. Satara, Maharashtra

- Applied vermiculture biotechnology in 1988, on sugarcane on saline soil. Irrigation with saline groundwater. Gradually expanded to 2 ha with successful results.
- Plot on Vermiculture yielded 125 tons/ha of sugarcane from plantation crop as well as from two rattoons.
  Control with chemicals and FYM yielded 100 and 75 tons/ha from plantation and the first rattoon respectively. Second rattoon was not taken.

	Net Profit, Rs./ha	
	Vermiculture Plot	Chemical Plot
Plantation Crop	28,750	26,250
First Rattoon	46,250	18,750
Second Rattoon	46,250	

- Results of soil-analysis showed marked improvements in the soil productivity within a year. The vermiculture plot had :
  37% more N
  66% more P_2O_5
  10% more K_2O
  50% less electrical conductivity
  46% less chlorides,
  than the chemical plot.

- Vermiculture produced sugarcane with 3-4 extra brix and lesser salts.

5.2 CASE 2 : SUCCESSFUL GRAPE FARMER

Jayant V. Barve

Vita (Phone : 141). Dist. Sangli, Maharashtra

- Grape planted on eroded wasteland.
- Basal application of vermicastings : 5 tons/ha
- Cowdung and agricultural residues (including fully grown weeds raised as intercrop) used for mulching.
- No chemicals put in the soil, but sprayed on foliage, according to the need.

Results :

- The orchard was healthy throughout and there were no nutrient deficiencies visible.
- 15 pesticide sprays (of lesser concentration) were applied in the first year - against 70-80 sprays normally (in chemical farming). The number of sprays went down in the second year.
- Yield was normal, however better price fetched due to superior quality (lustre, taste, higher shelf-life etc.). 90 per cent of the produce was exported.

- Input costs reduced from Rs. 1 lakh to Rs. 40,000 per ha.
- There was 75% saving in the water requirement of the crop.
- Periodic soil-analysis showed drastic improvements in the soil fertility :

★ Original pH	:	8.3
Afer 6 months	:	7.4
After 12 months	:	6.9
★ Original available potash	:	62.5 kg/ha
After 6 months	:	252 kg/ha
After 12 months	:	800 kg/ha

Petiole analysis, on 45th day from the date of October pruning showed increased concentrations of nutrients :

K was 2.5% (against 1.0% normally)
Fe was 677 ppm (against 200 ppm)
Cu was 203 ppm (against 78 ppm)
Ca was 2.15% (against 1.5%)
Mg was 1.22% (against 0.36%)

5.3 CASE 3 : SUCCESSFUL VEGETABLE FARMER

Madhusoodan G. Khamkar
Bhandgaon (Bavda), Tal. Indapur
Dist. Pune, Maharashtra

- Tondai (cucurbit) planted on saline soil
- Irrigation with saline groundwater

Results :

- pH improvement from 8.2 to 7.3 in 1 year
- Increase in water-holding ability of the soil
- Improvement of the soil-structure
- Disappearance of salt-crustation on the surface
- Produce with better quality, fetching 30 per cent higher price
- Performance of 3 years (with chemicals) and 2 years (with Vermiculture) is summarised as follows :

Chemical Plot

Inputs : For 1 acre	Rs./Year
1. Chemical fertilizers	2,700
2. Organic fertilizers	2,340
3. Pesticide Sprays 18 Nos. x 100	1,800
4. Weeding (6 times x 250)	1,500
5. Cultivation (3 times x300)	900
6. Irrigation (33 times x 15)	495
Total Inputs	9,735

Vermiculture Plot

Inputs : For 1 acre	Rs./Year
1. Vermicastings (divided over 5 years)	800
2. FYM, 15 Cartloads	450
Organic fertilizer	980
Mulching	500
3. Pesticide Sprays 6 Nos. x 100	600
4. Weeding	—
5. Cultivation	—
6. Irrigation (23 times x 15)	345
Total Inputs	3,675

	Rs./Year		Rs./Year
Soil depreciates	+ 1,000	Soil appreciates	— 1,000
Real Expenditure	10,735	Real Expenditure	2,675
Average yield : 23,800 kg		Yield : 22,710 kg	
Returns (@ Rs.2/kg)	57,600	Returns (@ Rs.2.6/kg)	59,046
Expenditure	10,735	Expenditure	2,675
Profit	46,865	Profit	56,371

6. About Ourselves :

Bhawalkar Earthworm Research Institute (BERI) was established in 1981 by Mr. Uday S. Bhawalkar (a chemical engineer from IIT Bombay), and Mrs. Vidula U. Bhawalkar (an electronic engineer).

Objective :
To apply vermiculture biotechnology to:
— Environmental protection, and
— Sustainable agriculture, wasteland development.

Background :
In order to achieve the said objective :
— BERI evolved processes for solid and liquid wastes management over 8 years of practical work at the site of Mr. Bhawalkar, the director. This was followed by his involvement in the Ph.D. work related to vermiculture biotechnology at the Indian Institute of Technology, Bombay.

Recognitions:

— Mr. Bhawalkar was honoured by the prestigious Rolex Award for Enterprise Secretariat by his inclusion in their book - "Spirit of Enterprise - 1990".

— BERI received an "Outstanding Exhibit" - award at the National Fair on Water Management in Agriculture, Madras, March 1990. The exhibit was a live demonstration of purification of wastewater by the BV process to get water for irrigation and vermicastings, the effective biofertilizer.

— In addition to more than 30 national seminars, Mr. Bhawalkar presented papers in 6 major international conferences, namely:

1. Water & Wastewater 1990 Conference,
   Barcelona, Spain, April 1990

2. 4 th International Symposium on Earthworm Ecology,
   Avignon, France, June 1990

3. Food Industry Environmental Conference,
   Atlanta, USA, November 1990

4. Low External Input Sustainable Agriculture (LEISA) Conference,
   Amsterdam, The Netherlands, April 1991

5. International conference on Appropriate Waste Management Technologies,
   Perth, Australia, November 1991.

6. Management of Wastes and By-product Utilization in Agro-industrial and Livestock Units,
   AGRO-UETP Conference, Athens, Greece, February 1992.

Present Activities :

BERI undertakes, on turnkey basis, the setting up of plants for solid and liquid wastes management, aimed at treating non-toxic organic wastes from cities, dairies, sugar mills, distilleries, slaughterhouses, tanneries, pulp and paper mills and various food-processing units.

BERI continues to be actively involved in sustainable agriculture and wasteland development. Vermiculture biotechnology is being successfully used by farmers on diverse crops such as - sugarcane, grape, guava, banana, coconut, pomegranate, chickoo, ber, vegetables etc., in different agro-climatic conditions in India.

Biotech Consortium India Limited (BCIL), New Delhi, set up by the Department of Biotechnology (DBT) and all India financial institutions (led by IDBI), has also identified vermiculture as potential appropriate biotechnology.

BERI has entered into an association with BCIL to actively promote this technology in India through its techno-financial linkages with technical/research institutions, government agencies/departments and industries.

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Discover yourself how the worms

- **can get rid of wastes to produce resources**
- **reduce soil erosion**
- **improve the soil productivity**
- **reduce dependence on imported, energy-rich chemicals**
- **help groundwater-recharge**
- **protect groundwater from getting polluted**
- **help in wasteland development**
- **help economy of The Third World countries.**

It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organised creatures (worms).

— Charles Darwin (1881)