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Environmental-Economics of Crop Production by Vermiculture: Economically Viable & Environmentally Sustainable Over Chemical Agriculture

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INTRODUCTION: THE ECONOMIC EVIDENCES FOR VERMICOMPOST AS AN EFFICIENT AND AFFORDABLE CROP NUTRIENT FOR THE GLOBAL FARMING COMMUNITY

The new economic theory of development today is '*Environmental-Economics*' which advocates for judicious balance between 'economy and ecology' in all developmental programs including agricultural development and amalgamation of 'economic development' programs with 'ecological conservation' strategies to usher in the era of sustainable development. The new economic philosophy of development also stresses mankind to switch over from the 'fossil fuel (petroleum products) based economy' to 'renewable resource based & waste recycling based economy'.

We have to understand that every natural resource, commodity, goods and services that we use from the environment has an 'environmental cost' (the hidden cost of environmental damage & repair while the raw material is procured from the earthly resources) other than its 'economic cost' (the cost of processing, manufacturing and trading) and only after adding the two costs, we arrive at the true cost of the product. There may be 'social cost' as well in the form of impaired human health and quality of life. We only pay for the cost of food grown in farms and its processing and transport. We never pay for the damage done to the environment due to production and use of chemical fertilizers and pesticides in their factories. Conventional economists are not bothered to deduct the cost of environmental damage (e.g. degradation of farmland & soil) and the cost of environmental repair and restoration (e.g. soil regeneration and management of degraded lands) from the GNP of nations. But the environmental-economists do (189).

The cost of production of vermicompost is simply insignificant as compared to chemical fertilizers. While vermicompost is produced from a 'cheap raw material' (community wastes including farm wastes) which is in plenty all over the world and is growing in quantity with the growing human population, the chemical fertilizers are obtained from 'petroleum products' which are not only very 'costly raw materials' but also a 'vanishing resource' on earth. And while vermicompost can be produced 'on farms' by all farmers, big and small, the chemical fertilizers has to be produced in 'factories' at a high economic and environmental cost. This means vermicompost can be afforded by all farmers. The worms itself becomes an economically valuable products for the farmers to be sold to fishery, poultry, dairy and pharmaceutical industries.

PRODUCTION & USE OF VERMICOMPOST-ENVIRONMENTALLY PROTECTIVE AND ECONOMICALLY PRODUCTIVE

Vermicompost production & use is an 'environmentally friendly, protective and restorative' process as it diverts wastes from ending up in landfills & also reduces emission of greenhouse gases (GHG) due to very small amount of energy used in its production process. Application of vermicompost in farm soil works as soil conditioner and help in its regeneration by improving its physical, biological and chemical properties.

Vermicompost production is also an 'economically productive' process as it 'reduces wastes' at source and consequently save landfills space. Construction of engineered landfills incurs 20-25 million US dollars upfront before the first load of waste is dumped. Over the past 5 years the cost of landfill disposal of waste has increased from $ 29 to $ 65 per ton of waste in Australia. Then, landfills have to be monitored for at least 30 years for emissions of GHG and toxic gases & leachate (Waste Juice) which also incur cost. During 2002-2003, waste management services within Australia cost $ 2458.2 millions. Even in developing nations where there are no true landfills, dumping of wastes incurs high cost on local government.

Earthworms converts a product of 'negative' economic & environmental value i.e. 'waste' into a product of 'highly positive' economic & environmental values i.e. 'highly nutritive organic fertilizer' (brown gold) which improve soil fertility and enhance farm productivity to produce 'safe food' (green gold) in farms. Vermiculture can maintain the global 'human sustainability cycle'-i.e. producing food in farms back from food & farm wastes.

Vermicomposting is a self-promoted, self-regulated, self-improved & self-enhanced, low or no-energy requiring zero-waste technology, easy to construct, operate and maintain. It excels all other waste conversion technologies by the fact that it can utilize waste organics that otherwise cannot be utilized by others. It excels all other biological or mechanical technologies for production of 'bio-fertilizer' because it achieves 'greater utilization' than the rate of 'destruction' achieved by other technologies and the process becomes faster with time as the army of degrader worms and the decomposer microbes multiply in millions in short time (171 & 174). Earthworms involves about 100-1000 times higher 'value addition' in any medium (composting wastes or soil) wherever it is present (9 & 10).

PRODUCTION & USE OF CHEMICAL FERTILIZERS -AN ENVIRONMENTALLY DESTRUCTIVE & ECONOMICALLY UNPRODUCTIVE PROCESS

Production of chemical fertilizers in industries is an 'environmentally damaging' process in its entire life-cycle, since harnessing of raw materials from the earth crust, to their processing in factories and their use in agriculture farms. It generates huge amount of toxic and hazardous wastes & pollutants at every stage of production and use. It also uses copious amount of energy in production process and emits huge volumes of greenhouse gases (GHG).

It is an 'economically unproductive' process of development. Huge money has to be spent on infrastructure development for production of chemical fertilizers and in installations of equipments for pollution control, transport and then on safe disposal of hazardous waste in engineered landfills. Its application in farms pollutes the soil and water bodies & kills beneficial soil organisms with severe economic & environmental implications.

LOWER COST OF FOOD PRODUCTION BY VERMICULTURE

A matter of considerable economic and environmental significance is that the 'cost of food production' by vermiculture will be significantly low by more than 60-70% as compared to chemical fertilizers and the food produced will be a 'safe chemical-free food' for the society. It is a 'win-win' situation for both producers (farmers) and the consumers (feeders). The cost of production of vermicompost is simply insignificant as compared to chemical fertilizers. While the former is produced from 'human waste'-a raw material which is in plenty all over the world, the latter is obtained from 'petroleum products' which is a vanishing resource on earth. Vermicompost can be produced 'on-farm' at low-cost by simple devices, while the chemical fertilizers are high-tech & high-cost products made in factories (124).

As vermicompost also helps the crops to attain maturity and reproduce faster, it shortens the 'harvesting time' (175). This further cuts on the cost of production and also adds to the economy of farmers as they can grow more crops every year in the same farm plot.

Vermicompost application reduces use of chemical pesticides and cut cost: Widespread use of chemical pesticides became an important requirement for the growth of high-yielding varieties of crops which was more susceptible to pests and diseases. Continued application of chemical pesticides induced 'biological resistance' in crop pests and diseases and lograthmatically much higher doses are now required to eradicate them.

There has been considerable evidence in recent years regarding the ability of vermicompost to protect plants against various pests and diseases either by suppressing or repelling them or by 'inducing biological resistance' in plants to fight them or by killing them through pesticidal action. Pesticide spray was significantly reduced where earthworms and vermicompost were used in agriculture.(168 & 182). Our studies also indicate that use of vermicompost help in disease control by almost 75%. This significantly cut down on the cost of food production.

Vermicompost application reduces use of water for irrigation and cut cost: Studies indicate that vermicompost is able to retain more soil moisture thus reducing the demand of water for irrigation by nearly 30-40%. (175; 182 & 183).

BETTER GROWTH & HIGHER YIELD WITH LOWER AMOUNT OF VERMICOMPOST

Studies indicate that smaller amounts of vermicompost in fact promote better growth performances of crops. Subler (180) reported that in all growth trials the best growth responses were exhibited when the vermicompost constituted a relatively small proportion (10%-20%) of the total volume of the container medium. Valani (203) found that 200 gm of vermicompost applied in pot soils performed better growth in wheat crops than those with 400 gm & 500 gm of vermicompost. Singh (167) found that in the farm plots where vermicompost was applied in the 2nd, 3rd and 4th successive years, the growth & yield of wheat crops increased gradually over the years at the same rate of application of vermicompost i.e. @ 20 Q/ha. In the 4th successive year the yield was 38.8 Q/ha which was very close to the yield (40.1 Q/ha) where vermicompost was applied @ 25 Q/ha

Use of vermicompost in farm soil eventually leads to increase in the number of earthworm population in the farmland over a period of time as the baby worms grow out from their cocoons. It infers that slowly over the years, as the worms build up the soil's physical, chemical & biological properties, the amount of vermicompost can be slowly reduced while maintaining the same yield. The yield per hectare may also increase further as the soil's natural fertility is restored & strengthened. In a study in Australia, Webster (206) found that vermicompost increased yield of 'cherries' for three (3) years after 'single application'. Yield was much higher when the vermicompost was covered by 'mulch'. At the first harvest, trees with 5 and 20 mm vermicompost plus mulch yielded cherries of the value of AU $ 63.92 and AU $ 70.42 respectively. After three harvests, yield per tree were AU $ 110.73 and AU $ 142.21 respectively for the 5 mm and 20 mm vermicompost with mulch. With vermicompost alone (without mulch), trees yielded cherries of AU $ 36.46 per tree with 20 mm vermicompost in the first harvest and after three harvest AU $ 40.48 per tree. Webster (206) also studied the agronomic impacts of compost in vineyards and found that the treated vines produced 23% more grapes due to 18% increase in bunch numbers. The yield in grapes was worth additional AU $ 3,400/ha.

INCREASINGLY GREATER AMOUNT OF CHEMICAL FERTILIZERS ARE NEEDED TO MAINTAIN GROWTH AND YIELD

On the contrary, in chemical agriculture, the amount of chemicals used per hectare has been steadily increasing over the years to maintain the same yield of previous years as the soil became 'addict'. Nearly 3 - 4 times of agro-chemicals are now being used per hectare what was used in the 1960s. And the cost of chemical fertilizers has also been steadily increasing since then. In Australia, the cost of MAP fertilizer has risen from AU $ 530.00 to AU $ 1500.00 per ton since 2006. There is also significant loss of chemical fertilizer from the farm soil due to oxidation in sunlight. Suhane (182) calculated that upon application of 100 kg urea (N) in farm soil, 40-50 kg gets oxidised and escapes as 'ammonia' (NH_3) into the air, about 20-25 kg leaches underground polluting the groundwater, while only 20-25 kg is available to plants.

SIGNIFICANTLY LOWER AMOUNT OF VERMICOMPOST IS NEEDED TO SUPPORT CROP GROWTH AND YIELD AS COMPARED TO CONVENTIONAL COMPOST

Our studies indicate that vermicompost is several times more powerful crop nutrient than the conventional composts and hence significantly lower amount of vermicompost is required for crop growth and production. Suhane (182) asserts that is at least 4 times more nutritive than cattle dung compost. In Argentina, farmers who use vermicompost consider it to be seven (7) times richer than conventional composts in nutrients and growth promoting values (132).

Atiyeh (17) found that the conventional compost was higher in 'ammonium', while the vermicompost tended to be higher in 'nitrates', which is the more available form of nitrogen to promote better growth and yield. They also found that vermicompost has higher N availability than the conventional compost on a weight basis and the supply of several other plant nutrients e.g. phosphorus (P), potassium (K), sulfur (S) and magnesium (Mg), were significantly increased by adding vermicompost as compared to conventional compost to soil. Then. vermicompost retains nutrients for long time and while the conventional compost fails to deliver the required amount of macro and micronutrients including the vital NKP (nitrogen, potassium & phosphorus) to plants in shorter time, the vermicompost does (42 & 180).

Above findings were experimentally verified by Suhane (183) who found that while on application of vermicompost @ 25 quintal/hectare on farm wheat crops the yield was 40.1 Q/ha, on application of cattle dung compost @ 100 Q/ha (4 times of vermicompost) the yield was just over 33 Q/ha which is about 18% still less than that on vermicompost.

COMMERCIAL VERMICULTURE: A GOOD BUSINESS OPPORTUNITY, POTENTIAL TO CREATE & SUPPORT ALLIED INDUSTRIES & COMBAT POVERTY

Vermiculture is a growing industry not only for managing waste and land very economically but also for promoting 'sustainable agriculture' by enhancing crop productivity both in quantity & quality at significantly low economic cost than the costly agrochemicals (39).

Earthworms not only converts 'waste' into 'wealth' it itself becomes a valuable asset as worm biomass. Large-scale production of nutrient rich 'vermicompost' (especially from the municipal solid wastes) with potential to replace chemical fertilizers and protein rich 'earthworms' can be a good business opportunity today with awareness growing about use of these products in agriculture and other allied industries (86). MSW is growing in huge quantities in every country with growing population and there will be no dearth of raw materials for production of vermicompost.

Vermiculture have also enhanced the lives of poor in India and have generated self-employment opportunities for the unemployed. It has become good source of livelihood for many. In several Indian villages NGO's are freely distributing cement tanks and 1000 worms and encouraging men & women to collect waste from villages & farmers, vermicompost them and sell both worms and vermicompost to the farmers (98). People are earning from Rupees 5 to 6 lakhs (Approx. AU $ 15-20 thousands) every year from sale of both worms and their vermicompost to the farmers. Mostly they use farm waste and also municipal solid wastes (MSW) collected from streets & waste dumpsites.

It is estimated that one (1) ton of earthworm biomass on an average contain one (1) million worms approximately. One million worms doubling every two months can become 64 million worms at the end of the year. Considering that each adult worm (particularly *E. fetida*) consume waste organics equivalent to its own body weight everyday, 64 million worms (weighing 64 tons) would consume 64 tons of waste everyday and produce 30-32 tons of vermicompost per day at 40-50% conversion rate (205).

In any vermiculture practice, earthworms biomass comes as a valuable by-product and they are good source of nutritive 'worm meal'. They are rich in proteins (65%) with 70-80% high quality essential amino acids 'lysine' and 'methionine' and are being used as feed material to promote 'fishery', 'dairy' and 'poultry' industry. They are also finding new use as a source of 'collagen' in the manufacture of pharmaceuticals and in the making of 'antibiotics' from the ceolomic fluid as it has anti-pathogenic properties.

CONCLUSIONS AND REMARKS

If vermi-products (worms, vermicompost & vermiwash) are able to replace 'agrochemicals' in agriculture & horticulture production and protein rich worms becomes pro-biotic food for fishery, dairy and poultry production, it would truly help achieve greater 'sustainability' in production of 'safe chemical-free food' for mankind in future.

The technology is being commercialized all over the world for mid-to-large scale vermicomposting of most organic wastes (food & farm wastes & green wastes and also the sewage sludge) and several companies have come up in the last few years in U.S., Canada, New Zealand, Japan and France. The Envirofert Company, New Zealand, is vermicomposting thousands of tons of green waste every year. They claim that each worm eat the cooked green waste at least 8 times leaving an end product which is rich in key minerals, plant growth hormones, enzymes and beneficial soil microbes. Envirofert is also planning to vermicompost putrescible food waste from homes, restaurants and food processing industries in New Zealand. They intend to process approximately 40,000 tones of food wastes every year to produce vermicompost which would eventually replace chemical fertilizers in farm production in New Zealand. (www.envirofert.co.nz)

Switching over to sustainable agriculture by vermiculture can truly bring in 'economic prosperity' for the farmers and the nations with 'environmental security' for the earth.

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Useful websites on vermiculture studies

http://www.alternativeorganic.com (Good Earth People, Canada).
http://www.kvksmp.org (Farmers Training on Vermicomposting at RAU, Bihar, India).
http://www.rirdc.gov.au (Australian Govt. Pub. On EARTHWORMS).
http://www.vermitech.com (Australian Company in Vermiculture Business).
http://www.vermitechnology.com (U.S. Company in Vermiculture Business).
(http://www.wormwoman.com (Mary Appelhof: Author of Classic Book 'Worms Eat My Garbage-Sold over 3500 copies).
http://www.wormdigest.org ('Worm Digest'-A Quarterly Magazine).
http://www.wormresearchcentre.co.uk (Earthworm Research Center in UK).

Relevant Books by Dr. Rajiv K. Sinha

1. Sinha, Rajiv K and Rohit Sinha, 2008. Environmental Biotechnology (Role of Plants, Animals and Microbes in Environmental Management) (pages 315), Aavishkar Publishers, India; ISBN 978-81-7910-229-9.
2. Sinha, Rajiv K., 2007. Sustainable Development (Striking a Balance between Economy & Ecology), (pages 340), Pointer Publisher, India; ISBN 978-81-7132-499-6.
3. Sinha, Rajiv K., 2003. Sustainable Agriculture: Embarking on the Second Green Revolution, (pages 350), Surabhee Publisher, India; ISBN 81-86599-60-6.