Building Circular Economy Models for Recycling Black and Grey Water for Food Security

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Introduction and Background

Economic development of a region where agriculture is the mainstay of livelihoods of majority population, encompasses two crucial aspects- inclusive growth and poverty reduction. If the agriculture sector fares well, both these vital aspects strengthen, resulting in sustained economic development for the region. The state of Tamil Nadu has always performed well ahead of other states with a stellar record production of 10.1 million tons of food grains in the year 2011-12 and, highest productivity of sugarcane and other important crops such as oilseeds and maize. Unfortunately, the growth rate in agriculture over the last decade has taken a dip because of rainfall deficit and limited or non-availability of sufficient water for irrigation.

Irregular rainfall over time has resulted in substandard production of standing crops dependent on rain-fed conditions. There is a need for renewed innovative methods to meet the ever-increasing requirement of food, in view of the limited scope for expanding cultivation under irrigation.

Introduction to the Region Where the Innovation has Taken Place

The Nilgiris district in the state of Tamil Nadu in India is home to several indigenous communities, flora and fauna whose livelihood interaction is shaped by the water flow landscape. Nilgiris has a population of 7.35 lakhs with over 40 percent of total working population associated directly or indirectly with agriculture making it the principal source for livelihood in the region (Census 2011). Nilgiris is known for cultivating exotic vegetables such as carrots, beans, broccoli, Chinese cabbage, beetroot, garlic, strawberries etc.

As the state of Tamil Nadu faces frequent dry weather spells affecting tea plantations, horticulture and vegetable cultivation, farmers are in dire need of access to water and bringing moisture content back to soil. Hydro-electricity power generation also requires water in large quantity.

Natural sources of water such as ground water have been exploited inequitably and without considering the sustainability across the state. Scarcity of natural sources of water and increase in demand for water has meant exorbitant increase in price of water for irrigation purpose.

WASTE

WASTE, a Netherlands based organization in partnership with the Rural Development Organization (RDO Trust), Nilgiris has developed a model for producing high quality co-compost from waste water and faecal sludge for cultivation of exotic vegetables by women farmers in the district. In order to enable target consumers to buy the co-compost, WASTE has implemented **The Diamond Model** that provides tools for private financing alongside potential market linking strategies in addition to generating quality co-compost and providing access to treated grey water. The innovation has received monetary award and support from Securing Water for Food (SWFF). The aim of the innovation is to establish a local circular economy model in sanitation for agriculture that is scalable and enables women agri-entrepreneurs to have better quality of crops with market quality co- compost application and extend crop season to advance green growth in the Nilgiris. The cultivation of crops is essentially an interplay of inputs such as seeds, fertilisers, pesticides, water and credit which determine the production and productivity. It becomes pragmatic to utilise inputs more efficiently and diversify cultivation to more sustainable and higher value crops.

Inadequate treatment and disposal of solid and liquid waste leads to a massive waste management challenge within the area disrupting the ecological balance of the area. The innovation directly caters to this gigantic issue by converting waste water and faecal sludge into co-compost, therefore, addressing the waste treatment and disposal needs for the authorities. As part of innovation, two resource recovery parks were built nearer to villages, thereby making transportation of co-compost easy and cheap. This whole process of production of co-compost has huge potential of creating jobs, smoothening waste management, increasing agriculture productivity and reducing water stress in agriculture sector.

The Rural Development Organization (RDO Trust)

RDO Trust was founded in 1980 by the renowned social activist, Mr. N. K. Perumal. RDO trust is a non- profit, non-partisan and secular volunteer organization (VO) committed to work for the upliftment of indigenous communities of the Nilgiris. Since its inception, RDO trust has been instrumental in building capacities of rural communities across technological, social, educational and cultural development. Their exemplary work in skilling, training and empowering village level communities have garnered them trust and respect from communities, government and other stakeholders.

Given their incredible work and stellar reputation among the farming community, RDO Trust was evidently the first choice of WASTE for a local implementing partner. They have been working with rural women since years and wanted to invest in training them with newer farming technologies and practices. The target beneficiaries for this project are women agri-entrepreneurs in Self Help Groups (SHG) grouped into Farmer Producer Companies. The project is supported by 13 partners including Canara Bank, National Horticulture Board of India and Bremen Overseas Research and Development Association

(BORDA). The innovation was implemented for the first time in 2017 and has been in operation for two years now.

The case measures the impact of the recent innovation by WASTE in the water stress regions and explores the possibilities which navigates issues related to soil fertility, gender disparities, climate change, income changes, water management, irrigation practices and technologies and market dynamics of the region.

Achieving Efficiency in Resource Use

The intervention is a solution to multidisciplinary problems pertaining to the environmental pollution and agricultural crisis in the Nilgiris. It is known that faecal sludge and grey water possess high value of nutrients which are required for quality crop production. While chemical fertilizers are deteriorating the soil quality, soil improving actions have become must for sustainable farming. Although this calls for leveraging the nutrients available in the waste streams, it is important to recognize the bacterial contamination and high load of pathogens in these streams and arrange for its sufficient treatment for recycling.

Co-compost produced using faecal sludge and treated wastewater has the capacity to improve the ever-worsening soil conditions. Farmers in pursuit of higher production and profits try to use more chemical fertilizers that can yield short term benefits. However, it needs to be understood that chemicals not only affect the health of the consumers but also severely affect the soil productivity in the next seed sowing cycles resulting in lesser production in every next cycle. To stop the menace of this vicious cycle in future, there was an immediate need to incorporate highly organic resources.

Water management can be essentially looked upon into two major parts a) Resource availability and b) Resource management.

While availability of water concerns with the quantum of fresh water available for different applications, water resource management focusses on water supply and demand management followed by wastewater treatment and recycling. Although, all the sectors are important and contribute towards water security, the innovation presented here essentially focuses on treatment and recycling of the water as part of a strategy to address the water scarcity in the region. The prime reason for this particular focus is that the community as a root level stakeholder has limited intervention to make for water availability planning and water supply management. Whereas, recycling and wastewater management initiatives involves the local community and gives them ownership for water management resulting in benefits for them.

The Diamond Model

The model produces nutrient rich co-compost to be used as a soil conditioner for cultivation of exotic vegetables by women farmers in the district. The model focuses on four key areas for successful implementation of the program and to achieve sustainability in the agriculture sector -

- Farmers raising the demands
- Women SHG members involved with Farmers' Producer Company and managing the supply of co-compost
- Agri-marketing companies for managing finances
- Government authorities for implementation of the project focusing on treatment of faecal sludge and grey water.

Technical innovations within the model involves recycling of greywater and using treated water for irrigation in critical period of lower rainfall and dry seasons. The other innovation is focused on recycling of faecal sludge contained within the on-site sanitation systems of the region. With the presence of private emptying operators and government vacuum trucks, these containment systems are emptied regularly and the faecal sludge is transported for treatment to produce co-compost at the end. The co-compost unit is operated by women in cooperation with town panchayats by mixing faecal sludge and organic solid waste. Women farmers who procure the co-compost are members of the Women Farmers Producer Companies and Groups.

The innovation presented here answers both the agriculture challenges prescribed in the discussion, water scarcity and soil productivity in one single attempt. It not only addresses both the major challenges, it also solves the menace of solid and liquid waste management in the region for the authorities which is a win-win situation for all stakeholders. Additionally, the model also incorporated market linkages for continuous business for farmers cultivating exotic vegetables and has enabled mobilization of private finances to overcome economic challenges for the stakeholders involved.

Technology Details

The intervention has two major technical applications in the project – a) greywater recycling at local level and b) Faecal sludge recycling with organic solid waste using co-composting methods. Figure 1 explains the faecal sludge recycling and the treatment process flow.

Earlier, faecal sludge used to be collected and dumped at either open grounds at distant locations or into the nearest water bodies resulting into heavy contamination of the freshwater resources. Whereas, the intervention here collects the faecal sludge from the private vacuum truck operators, transports it to the treatment site and feeds into the system.

Vertical wetlands: The unit essentially acts as a solid liquid separation system where the faecal sludge is first fed upon its advent at the treatment plant. The wetland is constructed

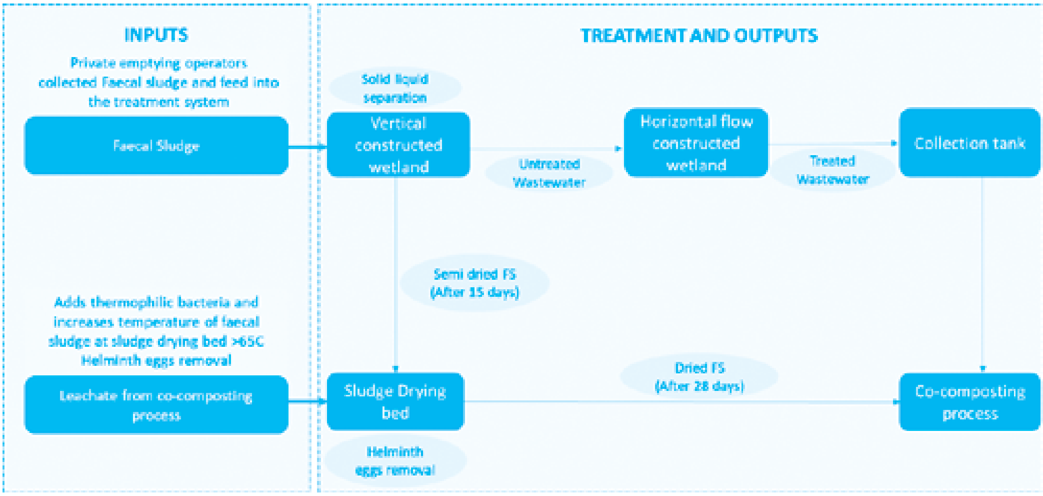


Figure 1: Treatment processes

using gravel and sand as filter media and native marsh plants to enable evapotranspiration for efficient dewatering. Heavy organic contents in the partially digested and fresh sludge, treatment system with only conventional sludge drying beds would not be able to achieve the output standards prescribed the pollution control board. Percolation of the liquid through filter media assures dewatering while plants root system maintains the permeability of the media and permits continuous addition of the faecal sludge.

The outputs are separated into two streams untreated water which is further treated and collected in a tank and dried faecal sludge which is conveyed to the sludge drying beds for further drying and co-composting is processed.

Horizontal wetlands: These units are designed to treat the liquid fraction of faecal sludge separated at the vertical wetlands. The unit is sealed at the bottom and sand-gravel matrix is used as filter media along with wetland plants like Phragmites or Typha. Several processes take place using bacteria and fungi to treat the waste water. The system treats the waste water and transports it to the collection tank from where it is conveyed to the composting area to be mixed with the composting heap or can be directly used in irrigation.

Sludge drying beds: Solid fraction of faecal sludge coming from the vertical wetlands is diverted to the sludge drying beds before conveyed for co-composting. The drying beds are essentially designed to further remove the water from the faecal sludge. One of the most important pollution standards is Helminth egg removal from the faecal sludge before putting it to any reuse. Sludge drying beds are fed by the leachate produced at the composting heap which raises the temperature at the drying bed to attain about 65^{o}C. This adds thermophilic bacteria to the beds and removes the helminth eggs from the sludge.

Co-composting: Composting process uses two separate feedstocks as part of the treatment and to produce nutrient rich compost. The quality of compost depends upon the content

Table 1.Resource Recovery Parks

Particulars	Units	Ketti	Adigarahatty
Vertical constructed wetlands			
Chambers	number	3	4
Treatment capacity per chamber	litres/day	8500	11000
Total treatment capacity	kL/day	25.5	44
Dimension	L*B*H	10.5*4*1	16*4.5*1
Area requirement	M^2	42	75
Horizontal constructed wetlands			
Chambers	number	1	1
Dimensions	L*B*H	4.5*2.5*1	4.5*3*1
Area requirement	M^2	11.25	13.5

of carbon and nitrogen in the mix. Apart from C: N ratio other factors like temperature, moisture content, size of particle and aeration. Ideal recommendation for C: N ratio in the compost should be in range of 25- 40:1 (Richard,1998). Ideal ratio for faecal sludge to solid waste is 1:2 to 1:3 for dewatered sludge and about 1:5 to 1:10 for liquid sludge (Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph. and Zurbrügg, C., 2014). The compost is used by the farmers as a soil conditioner for growing vegetables.

Key Challenges in Implementation

- As co-composting is dependent on the continuous availability of two feedstocks, faecal sludge and organic solid waste, it is important that the quantum of these feedstocks is managed proactively to run the plants as designed. As only the organic fraction of the solid waste can be utilised for composting process, waste segregation needs to be carried out precisely.
- The efficiency of the treatment processes and quality of co-compost produced highly depend on the ratio of the mixture of faecal sludge and solid waste. Therefore, regular emptying of the containment structures of the on-site sanitation systems needs to be followed for ensuring the availability of required faecal sludge for composting.
- Availability of grey water: Settlements that are located scattered from each other and do not have operational conveyance infrastructure for grey water faces difficulty in implementing the innovation. Scattered habitations would need bigger network of conveyance infrastructure and would also generate lesser greywater which would not suffix the farming requirement in the area. This ultimately leads to technical and economical unsustainability in implementing the innovation.
- Market fluctuations: Although the farmers have leveraged the opportunity of water availability in dry seasons through greywater recycling and have been able to produce more crops than before, market fluctuations have often resulted into losses for the farmers. While the compost is only 1 rupee costlier than the conventional fertilizer sold by the cooperative society, farmers are not discouraged to use this innovation. However, for buyers buying in ample amount, the differences can also add into the losses and hence mitigating the market problems assumes importance sooner or later.

- Cost of compost: The farmers producer company currently sells the compost at 5 rupees per kg excluding the cost of transportation. Although farmers have been benefitted by the innovation tremendously and want to continue using the same, a group of farmers have demanded for 50 percent cost reduction in the price of compost. While this seems difficult at first place as it involves significant treatment, laboratory tests and constant quality monitoring incurring a lot of cost for the authorities, there exists certain scope for subsidy or funds through corporate social responsibility that needs to be explored.

Impact

The impact is measured by carrying out ground level surveys with farmers.The survey involved 50 farmers who were selected to produce a representative sample of the entire region.Various impacts measured are presented in detail below.

Agriculture Activities

Table 2 shows the number of crops cultivated before and after using innovation by the respondents. It is evident from the table that substantial diversification is the outcome of the innovation. Farmers have observed better yield in terms of size, colour, skin and taste of the vegetables. Carrot, the golden crop of the Nilgiris, has performed well with 14 percent increase in the production after using innovation. Beetroot saw an increase of 12 percent in production whereas garlic and potato only saw an increase of 2 percent. Other crops such as beans, cabbage, radish, cauliflower, broccoli, zucchini also witnessed an increase in the production. Crops like flowers, strawberries, fenugreek and capsicum were introduced which were not produced before the access to innovation.

Water Security Benefits

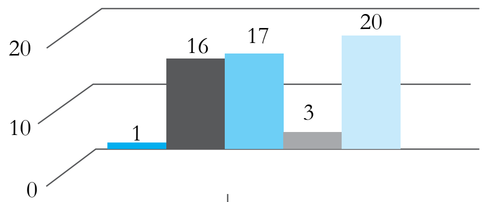
It was becoming a common practice amongst farmers to only cultivate 1/3 or 1/5 of their land due to paucity of water in this area. With the introduction of recycled grey

Table 2 Diversification in crops as a result of using innovation

	Carrot	Radish	Beetroot	Garlic	Peas	Beans	Potato	Cabbage
Number of crops grown before Innovation	35	2	13	12	1	4	19	4
Number of crops grown after Innovation	42	4	19	13	1	10	8	5

	Cauliflower	Broccoli	Zucchini	Flowers	Strawberry	Capsicum	Fenugreek
Number of crops grown before Innovation	1	3	1	0	0	0	0
Number of crops grown after Innovation	2	6	3	1	1	1	1

water, although limited, has allowed them to cultivate a part of additional land. Figure 2 below showcases 32 percent (16 out of 50) farmers could cultivate additional land unlike before and about 34 percent farmers were able to provide more irrigation than before. From a water scarce place to a situation where farmers could achieve more cultivation and irrigation itself signifies the value and benefits that the innovation has brought in the region.



		Freq.
	Can't say it's too early	1
	Could cultivate additional land	16
	Could provide more irrigation than before	17
	Could cultivate fodder and support dairy cattle	3
	Not using	20

Figure 2: Result of using recycled water

Soil Productivity Benefits

As shown in figure 3 below, 68 percent (34 out of 50) farmers declared that they have witnessed the reduction in the quantity of water used for irrigation purposes, citing the co-compost has increased the moisture retention in the soil making it viable to use less water which is an extreme benefit considering Nilgiris is witnessing the highest recorded dry season in the last decade.

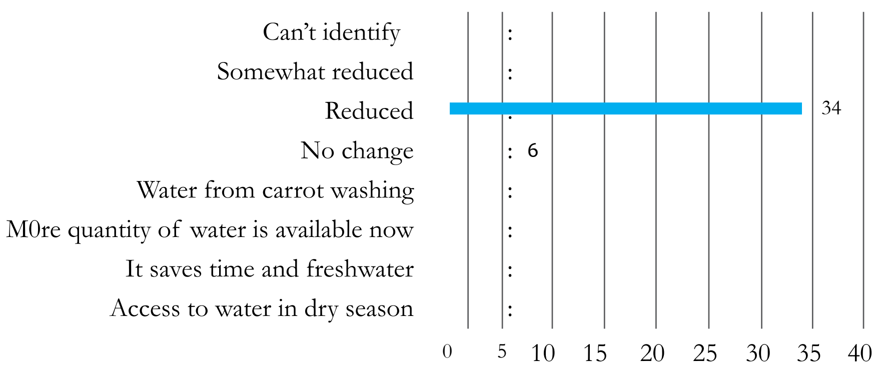


Figure 3: Water usage pattern

Crop Yield

As detailed in figure 4, 68 percent (34 out of 50) farmers saw their yields increase over the period the innovation was active in Nilgiris. All of those who observed increase in the crop yield felt that there was better quality and improved survival rates of their crops. 28 percent (14 out of 50) farmers reported to observe a substantial increase in the yield with 4 percent (2 out of 50) farmers reported to not using the innovation.

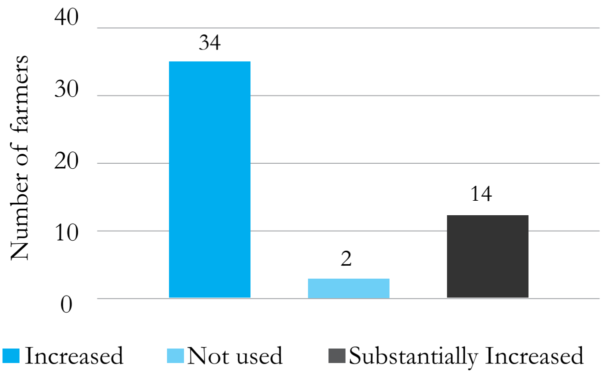


Figure 4 Change in crop yield

Crop survival rate

The survey concluded that farmers observed moisture retention in the soil, and using co-compost automatically reduced the usage of fertilizers ultimately enhancing the survival rate of the crops.

Increase in Income

Figure 5 below shows, 30 percent (15 out of 50) farmers reported to have somewhat increase in the income, owing to reduction in water labour, quantity of water used, and better quality of yield produced but also to the farmers' own productivity, price variations, and varying weather conditions. Out of 50 interviews, 14 farmers reported to have a significant increase in the income. 5 declared to observe very significant income change and 4 were not able to determine change in the income, while 1 farmer hoped for a better income in the next cycle.

Women Empowerment and Livelihood

Women were more enthusiastic about the innovation as they were provided with knowledge and techniques of farming through innovator's outreach program making them technically strong. The innovation enables women to become agri-entrepreneurs by selling co-compost to farmers. This led to ownership of farming practices and a shift of decision making amongst women.

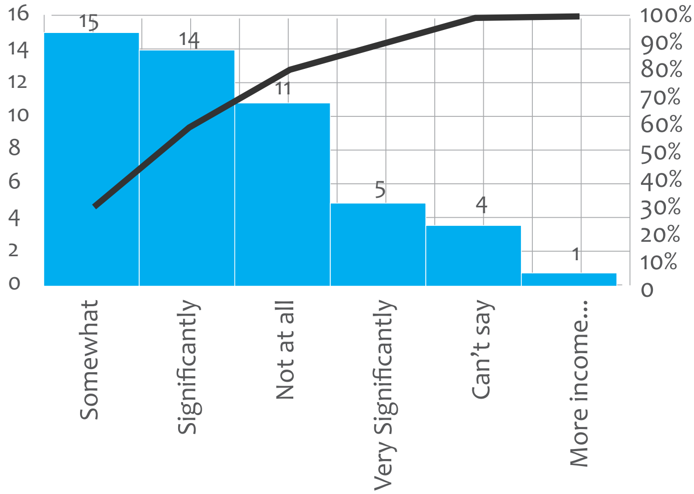


Figure 5: Increase in income

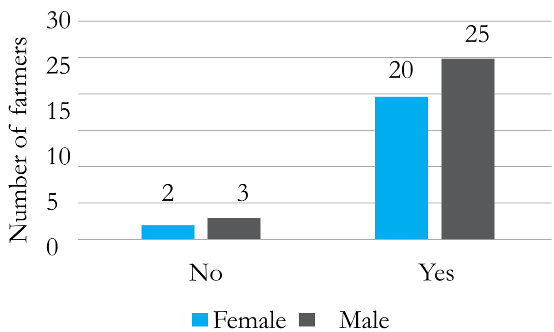


Figure 6: Desirability for compost: Gender view

Community Benefits and Livelihood

The impact and benefits of WASTE's innovation can be noted confidently for farmers across all regions. Although, benefits on community is difficult to measure but, one can observe tangible community cohesion as a result of innovation. The grey water unit installed in some of the villages has allowed small groups of farmers to use the water cyclically which brought community level sharing and adeptness to resources judiciously. For instance, farmers reported that quality of grey water is so good that it looks like filtered water. Additionally, this cyclic process is community driven which is also enabling them to take ownership of general cleanliness in the village. Good quality yield after using co-compost has led to building of confidence amongst farmers. A farmer stated

'I plan to use co-compost for tea farming as well now seeing better quality yield from neighbor farmers. This will help me improve my family income and give better education to my children'

As a result, it was observed that farmers exhibited a lot of trust in the innovation and started to treat it as a tool for community engagement. The youth in the region were also attracted towards agriculture, witnessing the positive changes. They now see farming as a sustainable profession, which otherwise was difficult to sustain in the past years because of acute dry season and climate change.

Conclusion

The intervention has made the community water literate and has created a sense of ownership within themselves for water management which has **promoted efficiency in resource use.**

The innovation primarily takes into account the concern of limited and expensive resources, such as water, seeds, compost, manure, labour, fertilizers and petrol, and figure out a sustainable, scalable and actionable route map to produce high quality co-compost from waste water and faecal sludge. The case provides insights on various parameters which may become essential to understand the future scope.

- Cost of co-compost should be reviewed, as it is important to monitor the market competition and operational cost to produce co-compost and how it can be reduced to meet farmer's request of lesser price.
- A service centre for farmers can be developed and maintained which disseminates the cognizance of new technologies, new and sustainable brands of inputs and scalable methods of sustainable farming to the farmers. Such centre would specifically be useful for women farmers who generally hesitate in learning new technologies or largely do not have access or voice to learn new processes. The centre can also enable capacity building of farmers teaching them a balanced application of fertilizers.
- Most of the farmers requested for more quantity of treated grey water. This depends upon the topography of the villages and also the contributing number of households. There seems to have flexibility in terms of designing and costing grey water unit. This insight may be explored further.
- Access to treated greywater in farms had become indispensable to them as they had to reduce the consumption of fresh water for irrigation to divert its use as drinking water in state of scarcity. Similarly, any region having high depletion of the freshwater sources or seems to reach that soon in the future, should adopt this model to make the best use of available resources. As the model involves multiple stakeholders having a shared goal, implementation of model has become easy and highly impactful.

- When it comes to food security, organic carbon content in soil is essential. Co-compost helps in retaining the carbon and sync it in the soil.
- The innovation had an impact over water usage, crops, yields and farmers' income. In order to build it further, the capacities of farmer producing companies need to be strengthened which would eliminate middle men. An EMI or a quarterly system for agri-inputs can be facilitated. Market has a huge cultural aspect towards pricing of a crop. Farmers purely rely on agents because they do not want to undergo any stress or risk, hence willingly loose a massive chunk of profits.

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