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Designing of a Self-reliant Farming System for Small Holder Farm in High Rainfall Areas

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Feasibility of a self-reliant farming system along with design aspects was worked out for small holder farm (1ha) in high rainfall areas (1500 mm). Vermicompost need was low when estimated based on the recommended dose of N, P and K as compared to the concept of nutrient removal. Amount of vermicompost required for meeting nutrient requirement of rice-legume cropping system (rice-blackgram 5.1 t ha^{-1}and rice-groundnut 8.8 t ha^{-1}) may be based on amount of N removed to strike a balance between high requirement for K and low requirement for P. For rice-maize cropping sequence, vermicompost need may be 12 t ha^{-1}by striking a balance between nutrient removal concept (15.9 t ha^{-1}) and state recommendation (7.7 t ha^{-1}). Growing of *Sesbania* crop for rice, inclusion of legume crop after rice and production of vermicompost is likely to meet the plant nutrient requirement. In 1 ha rainfedfarm, 90% area can be used for field crop including legume shrub and fodder on field bund. Remaining 10% area for water harvesting pond and dyke. After harvest of *kharif* rice, growing of blackram (45% area), groundnut (15% area) and spring maize (30% area) could meet animal feed besides the demand for farm family. To produce 8 t vermicompost, raw materials can be obtained from boundary plantation of *Glyricidia* (10 t fresh vegetation from 4 cuttings of 500 trees @5 kg tree^{-1}) and raw cow dung and bedding material.

(***Key words***: *Green Manure, Feed reliance, Nutrient reliance, Nutrient removal, Vermicompost, Water reliance*)

A self reliant farming system (SRFS) is envisaged as a system where the use of external sources for meeting the requirement of water, nutrient, feed and energy is minimized. For achieving the objective of sustainable agriculture, there is a need to develop SRFS which will conserve soil, water, and nutrients; and minimize the use of fossil fuels, chemical fertilizers, and synthetic pesticides. Organic, biological, or biodynamic farming practicescome closer to meeting such a concepton sustainability. One has to rely on crop rotation, animal manures, legumes, green manures, reduced tillage, mineral-bearing rocks, and biological pest control to maintain soil tilthand productivity, provide plant nutrients, and manage pests. In SRFS, in-situ water harvesting and use of solar energy reduces the requirement of external sources for meeting the water and energy requirement. This system is important in the context of increased cost of land, water, nutrients and energy. Natural ecosystems are extremely resilient and use only renewable sources of input resulting in high productivity and environmental quality. Solar energy application for water lifting is economically attractive and such pumps can be sold commercially to transform agriculture in less developed regions (Foster and Cota, 2014).

The sustainability of integrated crop livestock system relies on the complementarities between crop and livestock and the connectedness of livestock to the land (Naylor *et al.*, 2005; Wilkins, 2008). Animal manure represents the main nutrient input in smallholder farms (Braun *et al.*, 1997, Sheldrick *et al.*, 2003), as cash constrained farmers face increasing relative prices of mineral fertilizers (FAO, 2012). Under Indian conditions, the problem faced by farmer is further compounded by a chain of subsidy induced shortages as well as distance and time required to get fertilizer at the farm gate. Consequently, the small farmers have to rely increasingly on recycling of residues for conserving nutrients within the system (Alvarez *et al.*, 2014).Degradation of soil physico-chemical properties due to continuous use of chemical fertilizers is widely reported (Dick, 1992, Mann *et al.*, 2006, Rautaray, *et al.*, 2009; Simon and Czakao, 2014). In addition to the problems related to plant nutrient availability, it is reported that many regions in India are reaching the threshold of physical water scarcity (Amarasinghe *et al.*, 2007). In spite of large-scale expansion of irrigation systems, 55% of the gross cropped area in India is still rainfed and it is likely to continue in the near future (DWM, 2013a). Effects of climate change may further

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intensify the inherent problems of rainfed agriculture. So, water security at farm level through water harvesting is the option for such areas. Farms may be remote from markets and institutions resulting in added cost on transportation of farm inputsleading to low profit margin. Therefore, it is important to utilize the internal resources more effectively so as to reduce the use of external inputs and market dependence (Pretty, 1995). Thus a concept of SRFS has been evolved to make a rainfed farmer self reliant in terms of water, nutrient, animal feed and stationery power. This article evaluatesthe feasibility of such a system with design aspects.

MATERIALS AND METHODS

Estimation of requirement of inputs

Water

Rice- fallow or rice-legume on residual moisture is common crop rotation under rainfed conditions in Odisha plateau. To convert this crop rotation to irrigated one, irrigation has to be provided to rice to save it from uncertain distribution of rainfall and a minimum two supplementary irrigations to *rabi* legume crop. As per Srivastava (2001), for a site with seepage loss of less than 6 mmday^{-1}, runoff recycling system for providing reliable irrigation to a double crop rotation should have catchment command ratio of 3.0 or more, tank capacity of 1750 m^3 ha^{-1} command area and conveyance efficiency not less than 80%. For seepage loss in the range of 6-10 mm day^{-1}, the catchment command ratio should be 5.0 or more, tank capacity should be 1750 m^3 ha^{-1} command area. For seepage loss more than 10 mm day^{-1}, lining of the ponds is necessary.

This water harvesting system also provides sufficient amount of water for low consumptive use of on-dyke horticulture and non-consumptive water use for pisciculture. On-dyke horticultural crops get the benefit of capillary water from water harvesting pond. This design ensures transplanting of rice at optimum time (mid-July) in the event of insufficient rainfall in early stages. Often dry spell coincides with the reproductive phase (Singh *et al.*, 2010), especially, in late maturing varieties and/or late planted crop. Water harvesting system ensures that rice crop do not face any moisture stress during its growth period. In addition, sufficient water is available in post monsoon season for providing two irrigations of 75 mm each to post-monsoon season crops.

Plant nutrients

Based on nutrient removal concept

From Table 1, it can be observed that nutrient removal by a cropping system was highest for N followed by K and P. Nutrient addition through Sesbania green manuring for rice crop (*Oryza sativa*) is considered as 45 kg N, 3 kg P and 12 kg K (Rautaray *et al.*, 2003 a). Also, N supplied to soil through nodules, roots and fallen leaves of legume crop may be considered at 30-40 kg ha^{-1}. By this, net N requirement can be reduced to great extent followed by K and P. Deficit requirement of N, P and K can be met from vermicompost. For this purpose, nutrient content in vermicompostis considered at 1.5% N, 0.75% P and 0.7% K on dry weight basis.

Plant nutrient removal for rice crop was estimated as 111.5 kg N, 22.3 kg P and 85.6 kg K ha^{-1} (Rautaray *et al.*, 2002, Rautaray *et al.*, 2009) considering a grain yield of 4.5 t and straw yield of 5.5 t ha^{-1} with average nutrient content (1.5, 0.35 and 0.24% N, P and K in grain,respectively while 0.8, 0.12 and 1.36% N, P and K in straw). Similarly, nutrient removal for black gram (*Vigna mungo*) crop was estimated as 39.9 kg N, 4.5 kg Pand 34.1 kg K ha^{-1} considering a seed yield of 0.8 t and haulm yield of 2.15 t with average nutrient content (2.24, 0.18 and 0.9%, N, P and K in seed, and 1.02, 0.14 and

Table 1.*Nutrient removal for different rice based cropping system*

Cropping System	Nutrient removal (kg ha^{-1})			Nutrient added kg ha^{-1}				Vermicompost need tha^{-1}) to meet the requirement of			More Vermicompost need under nutrient removal concept (%)		
				In-situ green manuring			Legume crop						
	N	P	K	N	P	K	N	N	P	K	N	P	K
Rice-blackgram	151	27	120	45	3	12	30	5.1(3.3)	3.2(4.3)	15.4(5.4)	55	-26	185
Rice-groundnut	218	33	121	45	3	12	40	8.8(3.3)	4.0(4.3)	15.5(7.8)	167	-7	99
Rice-maize	284	60	197	45	3	12	0	15.9(7.7)	7.6(4.3)	26.5(7.8)	106	77	240

Figures in parentheses indicate amount of vermicompost needed (t ha^{-1}) to meet the recommended fertilizer dose (rice 80-17.5-33.3, blackgram 20-17.5-16.7, groundnut 20-17.5-33.3, and *rabi* maize 80-17.5-33.3 kg N-P-K ha^{-1} as per Agriculture Department, Government of Odisha).

1.25% N, P and K in haulm, respectively). Similar results are reported by Sarker *et al*. (2011). Thus, for a rice-black gram cropping system in 1 ha area, nutrient removal in grain and straw of both the crops is estimated at 151.4 kg N, 26.8 kg P and 119.7 kg K. Considering the nutrient addition through *Sesbania* green manuring for rice and the residual value of 30 kg N from blackgram crop, the amount of vermicompost needed to replenish the deficit N, P and K for the cropping sequence is estimated to be 5.1, 3.2 and 15.4 t, respectively.

Nutrient removal by groundnut crop (*Arachis hypogaea*) is estimated as 106 kg N, 11 kg P and 35 kg K ha^{-1} (Swain *et al*., 2007). The estimated nutrient removal is based on pod yield of 2.44 tha^{-1} with associated N, P and K uptake of 64, 5 and 9.5 kg, respectively, and haulm yield of 4.25 tha^{-1} with N, P and K uptake of 42, 6 and 25.5 kg, respectively. Thus, for 1 ha rice – groundnut cropping system, nutrient removal in grain and straw of both the crops may be estimated as 217.5 kg N, 33.4 kg P and 120.6 kg K. Considering the nutrient addition through *Sesbania* green manuring for rice and the residual value of 40 kg N from groundnut, amount of vermicompost needed to replenish the deficit N, P and K for rice-groundnut cropping sequence is estimated to bebe 8.8, 4.0 and 15.5 t, respectively.

Similarly, nutrient removal by spring/summer maize crop (*Zea mays*) after the harvest of wet season rice may be considered as 172.9 kg N, 38 kg P and 112.4 kg K ha^{-1} from a grain yield of 5.5 t ha^{-1} and straw yield of 8.9 t ha^{-1} (Chandrapala *et al*., 2010). Considering the nutrient addition through *Sesbania* green manuring for rice, amount of vermicompost needed to replenish the deficit N, P and K for rice-spring maize cropping sequence will be 15.9, 7.6 and 26.5 t, respectively. High vermicompost need under this cropping sequence is due to nutrient exhaustive nature of maize crop and absence of legume crop in dry season.

Based on recommended fertilizer dose

The recommended dose of N-P-K (kg ha^{-1}) by Agriculture Department, Government of Odisha for rice 80-17.5-33.3, blackgram 20-17.5-16.7, groundnut 20-17.5-33.3, and *rabi* maize is 80-17.5-33.3, respectively. Considering the nutrient added through green manuring and residual legume effect, the vermicompost requirement to meet the need for N, P and K is presented in parentheses in Table 1. The vermicompost requirement was higher under nutrient removal concept as compared to the recommended fertilizer dose by the State Department of Agriculture, except for P under rice-groundnut and rice-blackgram sequence. This difference was maximum for K (99% for rice-groundnut sequence to 240% for rice-maize) followed by N (55% for rice-blackgram to 167% for rice-groundnut sequence) and lowest in case of P (-26% to 77%). The low requirement of P under recommended fertilization as compared to nutrient removal concept may be due to consideration for high residual effect of P fertilizers in soil.

Vermicompost

Based on nutrient removal concept, amount of vermicompost required for meeting K requirement ranged from 15.4 t $ha^{-1}$for rice-blackgram cropping system to 26.5 t ha^{-1} for rice-maize system. Vermicompost required for meeting N requirement ranged from 5.1 t $ha^{-1}$for rice-blackgram cropping system to 15.9 t ha^{-1} for rice-maize system. Regarding P, vermicompost requirement varied from 3.2 to 7.6 t ha^{-1}.

For rice-blackgram cropping sequence, the vermicompost need will be 5.1, 3.2 and 15.4 t for meeting N, P and K requirement, respectively. If vermicompost is applied at 5.1 t ha^{-1} based on N equivalent alone, this amount will meet 160% of P and 33% of K need. In order to strike a balance between high requirement for meeting K removal and low requirement for P removal, vermicompost may be recommended based on N removal (5.1 t $ha^{-1}$for rice-blackgram system and 8.8 t ha^{-1} for rice-groundnut). For nutrient exhaustive cereal-cereal cropping sequence, vermicompost need is high based on nutrient removal concept. By striking a balance for vermicompost need between nutrient removal concept (15.9 t ha^{-1}) and state recommendation (7.7 t ha^{-1}) for rice-maize cropping sequence, average value (12 t ha^{-1}) is considered.

Rice-maize sequence in 0.3 ha will need 3.6 t vermicompost. Similarly rice-blackgram sequence in 0.45 ha will need 2.3 t and rice-groundnut sequence in 0.15 ha will need 1.3 t while plantation crops on dyke (0.035 ha) may be provided 0.8 t with total need of 8 t vermicompost for 1 ha farm.

To produce 8 t vermicompost (7.2 t for field crops and 0.8 t for plantation crops), size of vermicompost unit should be 18 feet x 5 feet x 2.5 feet. Capacity of such unit is to produce 2.67 t compost. Three batches of composting will produce about 8 t vermicompost per annum. About 24 t raw materials will be needed for producing 8 t vermicompost. Boundary plantation of *Glyricidia* can provide 10 t fresh vegetation from 4 cuttings of 500 trees @ 5 kg $tree^{-1}$. Raw cowdung from 3 cows and 1 calf per annum would be about 14 t which would meet the need for vermicompost (10 t) and fish feed (4 t). Maize straw and other crop residue may meet the deficit requirement of 4 ton raw material for vermicompost unit.

Energy

Since this runoff recycling system will be pump based, energy will be required to pump the harvested water. The total amount of water to be pumped will be about 450 mm assuming 300 mm for rice and 150 mm for post monsoon legume crop, which is 4500 m^3 for 1 ha farm. Assuming 50% pumping efficiency with 3 hp pump and a total head of 10 m, this will require about 250 kiloWatt hour energy per annum spread over 12-15 days per annum.

Fodder and feed

Considering the dung requirement for vermicompostunit and fish feed, 3 cows and 1 calf need to be reared in the SRFS unit. One Jersy cow yielding 20 L day^{-1} requires 30 kg green fodder day^{-1}. A dairy unit of 3 cows and 1 calf may require 100 kg green fodder day^{-1}. This requires cultivation of hybrid napier/bajra in 1200 m^2 area (field bunds and pond dyke). Dry fodder requirement through paddy straw will be about 4.38 t $annum^{-1}$ for the dairy unit considering the requirement of 4 kg cow^{-1}. Considering the concentrate : dry fodder ratio of 1, concentrate requirement per cow will be 4 kg and 4.38 t $annum^{-1}$ for the dairy unit. Protein requirement cow^{-1} day^{-1} is 250 g and considering additional requirement during mulching period, total protein need for the dairy unit is 330 kg. Maize grain contains 9% protein and 189 kg protein can be obtained from 3.2 t grain. For obtaining 2.1 t maize grain, 0.3 ha should be cultivated during spring/summer season. Fodder blackgram/groundnut contains 12% protein on dry weight basis. Cultivation of this food legume/groundnut in 0.6 ha area (0.45 ha blackgram and 0.15 ha groundnut) can yield 1.2 t dry haulm and provide 144 kg protein through feed.

Fish feed

For a fish pond with dimension of 750 m^2water area, rice bran requirement for fish feed will be 2 q. This can be available as by-product from milling of rice for family consumption. About 2 q oilcake will be required as fish feed and this can be obtained from 3.5 q oil seed or 5 q of groundnutpod. For this, cultivation of groundnut is required in 0.15 ha area. Raw cowdung (1 t) required as fish feed and pond enrichment will be met from dairy unit (1 cow will provide about 4 t dung).

RESULTS AND DISCUSSIONS

Water reliance

Based on our experience, in rainfed uplands in coastal Odisha with medium textured soil, the water depth in farm pond in October end is in full capacity (2.5 m depth) in years with normal monsoon. In November end, the water depth goes down to 2.2 m due to percolation and evaporation. Mean Monthly rainfall and evaporation of Bhubaneswar during the period 1985 to 2008 is presented in Fig. 1. There was surplus rainfall from the June to October to meet evapotranspiration demand while it is opposite for the period from the November to May. Bhubaneswar received about 73% of the total annual rainfall during the monsoon season (June-September), 15% during the post monsoon season (October-January) and 12% during the pre monsoon season (February-May).

One irrigation of 7.5 cm depth to legume crop in 0.6 ha area in December, two irrigations to maize crop (0.3 ha) and natural losses can bring down the water depth to 1.64 m towards end December. Second irrigation (7.5 cm) in January and natural losses can bring down the water depth further to 1.08 m in end January. Similarly, the water depth may reach 0.72 m in end February. Fish should be harvested when water depth reaches 0.4 m in mid March.

Nutrient reliance

Vermicompost can be produced using crop residue, nitrogen rich vegetation from farm boundary and cow dung.Crop rotation using food legume (groundnut and black gram), leguminous shrub on bund (*Glyricidia* /*Leucaena*), legume cover crops (*Sesbania*) and application of vermicompost can be useful for *in-situ* self-reliance regarding plant nutrients. Green manuring with *Sesbania in-situ* contributes about 45 kg N, 3 kg P and 12 kg K for transplanted rice crop (Rautaray *et al*., 2003 a & b). In the semi-arid tropics, residual N

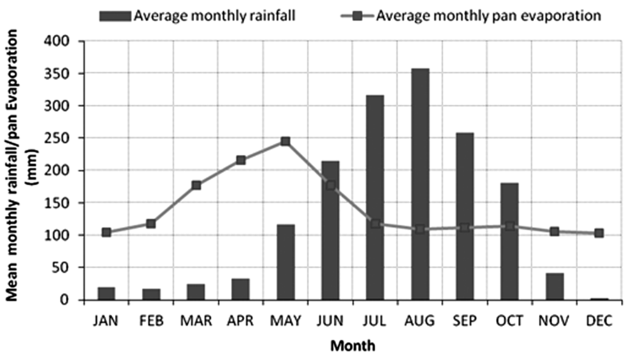

Fig. 1. *Average monthly rainfall and pan evaporation of Bhubaneswar (1985-2008)*

contribution bylegumes to the succeeding crop has been estimated to be usually equivalent to 30-40 kg N ha^{-1} (Rupella and Saxena, 1989, Rego and Burford, 1992). A lowerresidual value of 30 kg N was considered for blackgram crop. The nutrient contents of vermicomposts differ greatly depending on the raw material (Bansal and Kapoor, 2000). Nutrient content in vermicompost was considered as 1.5% N, 0.75% P and 0.7% K on dry weight basis. This value is assumed considering raw material as cowdung, paddy straw, *Glyricidea* and weed biomass. Nitrogen P and K content of 1.85%, 0.79% and 0.7% K in vermicompost is reported (DWM, 2013 a & b).

Feed Reliance

Growing of fodder crop on field boundary or waste land can provide green fodder for farm animals. The average productivity of hybrid napier/bajra as fodder crop is 300 t ha^{-1} from 6-8 cuttings. Planting of this crop on field bunds and on the pond dyke as third tier crop can provide enough green fodder. In addition, legume green fodder may be grown as inter crop. Haulms of groundnut and black gram are useful as dry fodder, especially for milching cows. About 30% offarmarea may be utilized for growing maize to produce concentrate animal feed. Maize grain, legume haulms and ground oil cake can meet the protein needs of farm animal.

Fish feed reliance

Composite pisciculture should be practiced for efficient utilization of feed from surface, column and bottom niches. Providing fish feed through organic sources (oil cake, cowdung and rice bran) has beneficial effects on protein and meat quality of fish. Intensive management on fish diseases and water quality may not be required under this semi-intensive system. Requirement of cash and dependence on market for fish feed can be avoided.

Solar energy supplementation

For reducing the dependence on conventional energy sources, use of solar energy can be attempted for lifting the harvested surface water. For running a 2 hp pump (outlet dia 2.0 inch) operated by solar energy, 150v DC Pump will be required. Max Head (50M) and flow of 3LPH at 13 m head can be achieved using this solar operated pump. Installation of solar power station will require an expenditure of Rs. 2.3 lakh and for promotion of solar energy, Govt. provides subsidy up to 90%.

CONCLUSION

In-situ bio and solar resources can be effectively recycled for designing a self reliant farming system, in which, the dependence on external sources for meeting the requirement of water, nutrient, feed and energy is minimized.

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