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Development and harnessing of water resources for livelihood improvement of smallholder farmers in Eastern India

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ABSTRACT

The study was carried out in two clusters of villages in Dhenkanalsadar block and Odapada block, respectively, in Dhenkanal district of Odisha, India. Agricultural technology interventions like construction of water harvesting structures (WHSs), multiple use of water in WHSs and crop diversification were done in the six identified study villages within two clusters. Ten WHSs distributed over six villages were constructed in farmers' field on participatory basis in which farmers paid a part of the expenditure. Multiple use of water in WHSs was done in terms of agriculture, on-dyke horticulture, vegetable cultivation, pisiculture, poultry and duckery to develop them as farming system models. Farmer groups were formed for vegetable cultivation and water melon cultivation by river lift irrigation. Adequate trainings and exposure visit of farmers were also conducted on water management technologies. The economic analysis of the farming system model showed that the internal rate of return (IRR) is 19.6% and benefit-cost ratio (BCR) is 3.65. The impact analysis on livelihood of farmers was studied as a function of physical assets, social assets, financial assets, human assets and natural assets of the farmers, before and after the interventions. The analysis indicated that maximum improvement occurred in physical assets (increase by 78%) followed by natural assets (66%). Mean value of overall standard of living of the farmers derived through addition of the mean values of five assets (ranged from 5 to 25) showed an increase from 10.24 to 14.15 indicating improvement of overall livelihood.

1. INTRODUCTION

Agriculture and allied sectors are important to Indian economy, accounting for 14.6% of the nation's GDP and about 12.55% of its exports (DES, 2017). About half of the population of India relies on agriculture as its principal source of income. But with increasing water demand from industrial and domestic sectors, there is mounting pressure on water availability for agriculture sector. India accounts for only about 2.4% of the world's geographical area and 4% of world's renewable water resources, but the country has to support about 18% of the world's human population and 15% of livestock (CWC, 2013). The net sown area in India has remained about 140 M ha since 40 years; and there has been sharp decline in average land holdings from 2.28 ha in 1970-71 to 1.16 ha in 2010-11 (DES, 2017). Thus there is an urgent need for site-specific development of water resources, technological intervention for efficient conservation, management and judicious utilization of resources leading to increased agricultural production in the region.

The increased farm production and income is expected to influence changes in livelihood of the farmers. The measure of livelihood gives an idea of the changes in standard of living of the farm families (Ghosh *et al.*, 2016). Livelihood of people depends on ensuring food, income and asset development at farmer's level. A livelihood is sustainable when it maintains or enhances the assets on which it depends. Many of the definitions of livelihood security currently in use are derived from the work of Chambers and Conway (1992). The idea of livelihood embodies three fundamental attributes: (i) possession of human capabilities (such as education, skills, health, and psychological orientation); (ii) access to tangible and intangible assets; and (iii) the existence of economic activities. The interaction between these attributes defines the livelihood strategy of a household. The sustainable livelihoods can be achieved through agricultural intensification, livelihood diversification, migration, etc. (Scones, 1997). The Department For International Development (DFID) framework (1999) identified five categories of assets or capitals *viz.,* human capital (skills, knowledge, health and ability to work), social capital (social resources and their interaction with other people and agencies), natural capital (land, soil, water, forests and fisheries), physical capital (roads, infrastructure, sanitation facilities, education and communication avenues) and financial capital (savings, credit, income from employment, trade and remittances). The 'rural livelihoods' are complex and wide-ranging (Ashley *et al.*, 2003). Therefore, multi-enterprise development through agriculture and allied sectors holds the key for development of rural economy (Mehta, 2009).

The plateau region of eastern India is one of the poorest in the country with more than 40% people living below poverty line (Srivastava *et al.,* 2009). This agro-ecological region (AER) comprising of north-western and western Odisha, Chhatishgarh, Jharkhand and southern districts of West Bengal has been classified as AER No 12 by ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, India (Sehgal *et al.,* 1992). The region is characterized by hot moist sub-humid type of climate with dry summers and mild winters, with agriculture being the major source of livelihood of the people. However, agricultural productivity in the region is very poor due to lack of water resources, technical knowledge, inaccessibility to quality planting materials and small holding of the farmers. Thus, investment in water resource development could potentially be an effective tool to increase the farm productivity and income leading to poverty eradication through an improved livelihood of these smallholder farmers. Badiger *et al.* (2016) did the economic analysis of impact of rainwater WHSs on farm income in north Karnataka. The investment on farm ponds was observed to be financially feasible and economically viable compared to *nala bund*. Sahoo and Behera (2017) evaluated water harvesting based integrated farming systems (IFSs) for resource recycling and livelihood security for marginal farmers in three disadvantaged districts of Odisha. The sustainable yield index and sustainable value index values were 0.84 and 0.47, respectively in pond based IFS models as compared to 0.10 and 0.03 in conventional cropping system. In the present study, development and harnessing of water resources was done and technological inputs were provided to the farmers considering a conceptual framework (Fig.1). The present study focuses on impact analysis of the interventions on livelihood of smallholder farmers.

2. MATERIALS AND METHODS

Study Area

The study area comprised of three villages *i.e.* Khallibandha, Nuagaon and Mandapala villages in the Dhenkanalsadar block (Fig. 2) and three villages *i.e.* Gunadei, Belpada and Kaunriapala villages in the Odapada block (Fig. 3) of the Dhenkanal district, Odisha. The study villages are situated on the bank of river Brahmani which is a major river of Odisha state. The area of the six study villages in two blocks is shown in Table 1.

Water Harvesting Based Farming System Models

Ten WHSs distributed over six study villages were constructed in the farmer's field in the year 2009-2010, in

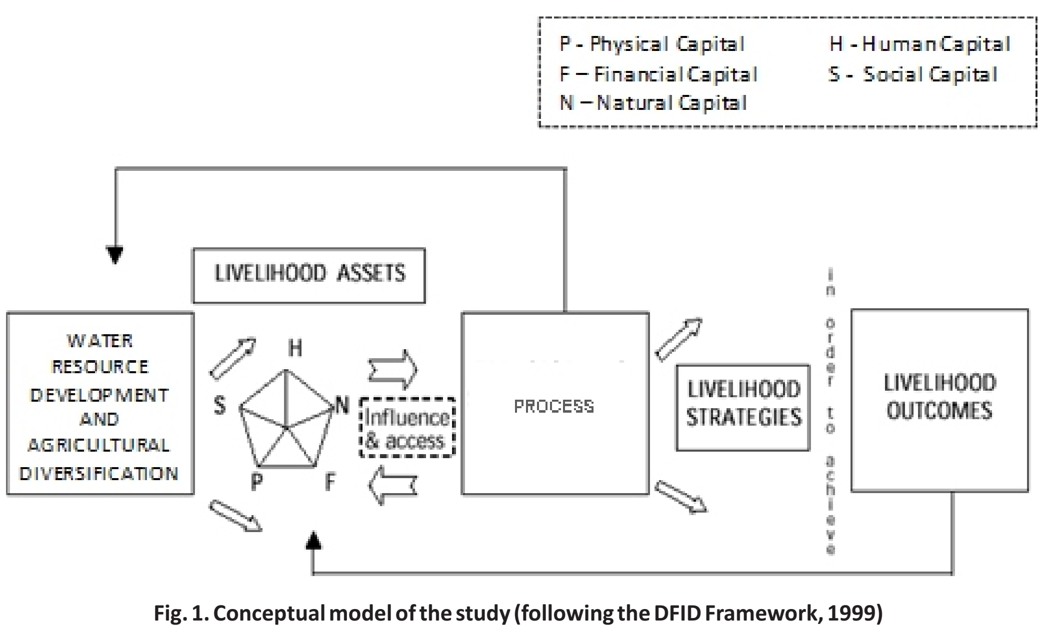

Fig. 1. Conceptual model of the study (following the DFID Framework, 1999)

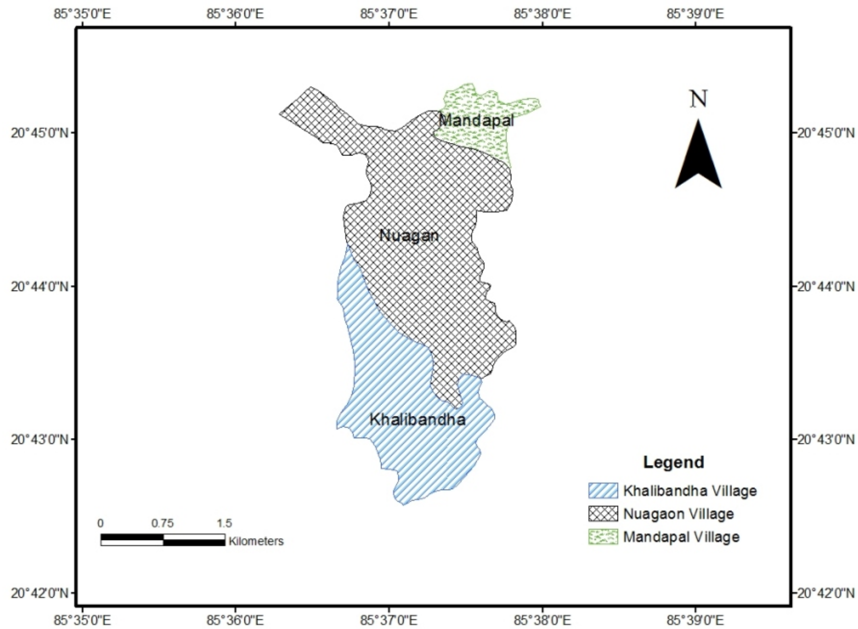

Fig. 2. Study area in Dhenkanalsadar block

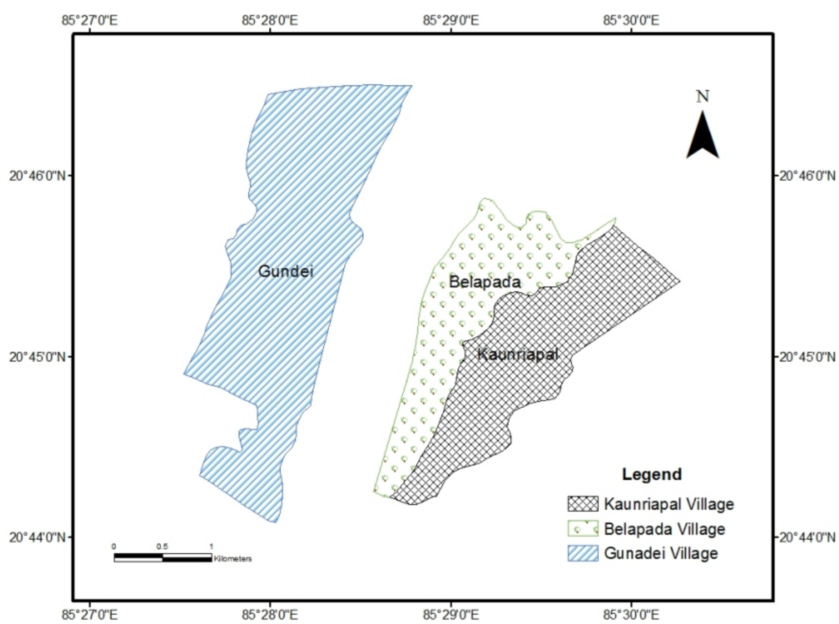

Fig. 3. Study area in Odapada block

Table: 1
Area of the study villages

Dhenkanalsadar block	
Village	Area (ha)
Khallibandha	247.26
Nuagaon	448.19
Mandapala	58.92
Odapada block	
Gunadei	436.82
Belpada	191.34
Kaunriapala	239.40

which the farmers agreed to meet a part of the expenditure, *i.e.* the construction of bunds around the ponds. The details of the ten WHSs including the village, areas and capacities of ponds are presented in Table 2. The volume of WHSs varied from a minimum of 200 m^3 (ponds P2 and P3) to a maximum of 2500 m^3 (pond P5). Multiple use of water in the WHSs was achieved in terms of agriculture, on-dyke horticulture, pisciculture, poultry, dairy, mushroom and vegetable cultivation to develop them as IFS models for a four years period of 2010-2011 to 2013-2014. Apart from supplementary irrigation to the paddy crop during dry spells in the monsoon season, the WHSs were also used as a source of water for agriculture in the post-monsoon season in addition to other multiple use components like poultry, dairy and mushroom cultivation.

The components of land area for the IFS units comprised of pond area, bund area, upland area and cultivated paddy area. The pond area was used for pisciculture, the bund area for on-dyke horticulture, and the upland area for dairy, poultry, mushroom and vegetable cultivation. Banana, papaya and drum stick were planted on the embankments around the pond as on-dyke horticulture. Vegetables like potato, brinjal, tomato, cabbage, cauliflower, ladies finger, cucumber, ridge gourd, cowpea, chili and onion were cultivated either in monsoon or post-monsoon season. The system adopted in the farming system unit represents the multiple use components adopted in the model (Table 2). The system 'rfhvpdm' represents an IFS unit with multiple use components of paddy cultivation (r), fish culture (f), on-dyke horticulture (h), vegetable cultivation (v), poultry (p), dairy (d) and mushroom (m) cultivation. Similarly, the system 'rfv' represents an IFS unit with multiple use components of only paddy cultivation, fish culture and vegetable cultivation. Agriculture, fish culture and vegetable cultivation was done by all the farmers whereas on-dyke horticulture, poultry, dairy and mushroom cultivation was adopted by only some of the farmers. On-dyke horticulture was done by the farmer only in farming system units P1, P4, P6, P7 and P8, whereas poultry was adopted in models P1, P4 and P8. All multiple use components, including dairy and mushroom cultivation, were done in only farming system unit P4.

Crop Diversification

Apart from the above ten beneficiary farmers, other farmers in the study villages were encouraged for crop diversification from paddy cultivation to vegetables, pulses, pisciculture and mushroom cultivation. Three farmer groups were formed in the Dhenkanalsadar block for water melon cultivation by river lift irrigation on the banks of river Brahmani. Pumps were provided to the farmer groups for lifting of irrigation water. In total, 40 farmers were involved in 3 groups and a total of 45 ha were put to cultivation of water melon. Two farmer groups were formed in the cluster of villages in Odapada block for vegetable cultivation by river lift irrigation. A group of farmers in Dhenkanalsadar block carried out mushroom cultivation. The water melon cultivation became a success in the area and spread to other farmer groups. Finally, they started exporting water melon to nearby bordering states.

Trainings and Exposure Visits

Six training programmes with one in each study village were conducted on advanced agricultural practices and water management technologies during the 4-years period. Apart from that, four exposure visits were conducted for farmers from both the cluster of villages to show them nursery management, crop care and management system under net house, drip and sprinkler irrigation systems, vermi-composting and organic farming and other technologies related to agriculture and water management.

Economic Analysis

The economic analysis was done by calculating the internal rate of return (IRR) and B:C ratio (BCR) of the system. The IRR is the rate at which the net present value (NPV) of the system becomes zero *i.e.* present value of future cash inflows are equal (Srivastava *et al.,* 2009). Mathematically, IRR is a root of a polynomial of degree 'n', which can have 'n' number of solutions. On simplifying, it can be estimated as follows:

$$PW_n = [INV(1-r)^n - B(1-x)^n](1-r)^n \quad ...(1)$$

The value of 'r' is increased till

$$\sum_{n=0}^{N=N-1} PW_n = 0 \quad ..(2)$$

Table: 2
Location and volume of water harvesting structures

Pond No.	Village	Pond area (m^2)	Total area (m^2)	Volume of WHS (m^3)	System adopted
P1	Khallibandha	300	4110	500	rfhvp
P2	Khallibandha	150	3550	200	rfv
P3	Khallibandha	150	3600	200	rfv
P4	Nuagaon	800	4510	1500	rfhvpdm
P5	Nuagaon	1400	16350	2500	rfv
P6	Mandapala	400	4090	1000	rfhv
P7	Kaunriapala	225	2015	350	rfhv
P8	Belpada	450	4170	750	rfhvp
P9	Belpada	200	3030	425	rfv
P10	Gunadei	400	4450	550	rfv

Note: Total area indicates pond area + bund area + upland area + paddy area; r- paddy cultivation, f- fish culture, h- on-dyke horticulture, v - vegetable cultivation, p - poultry, d - dairy, m - mushroom cultivation

Where, PW_n = present worth value in nth year, INV = initial investment in the project, r = internal rate of return, n = year, N = life of the system, B = annual benefit in first year, and x = expected rate of increment in annual benefits.

For calculation of BCR, discounted net worth method (Helweg and Sharma, 1983) was used for life of 20 years at discount rate of 10%, the prevailing interest rate for medium term loans for farming purpose.

Impact Analysis

Impact on the farming situation of the farmers on adoption of a technology was realized through a comparison of farming pattern, acreage, production and gross income before and after adoption of the technology. Impact analysis in the current study was done by comparative position of physical, social, financial, human and natural assets of the farmers before and after adoption of the intervention as the livelihood was defined as the function of these assets.

Physical assets included the type of housing condition, sanitation, conveyance, electric, cooking and communication facility. Social assets mainly referred to the recognition, social and political participation, active involvement in developmental works, common services used and group membership pattern. Financial assets were measured on the basis of sources of income, kinds of savings and investments, lending and borrowing. Human assets involved language competencies, education/literacy, management skill and mobility. Natural assets were the natural resources holdings of the farm family *viz.,* farm size, irrigated land, livestock holding, poultry and fishpond. All the above-mentioned variables under five types of assets were measured on the basis of the responses of farmers on a 5-point continuum scale (minimum and maximum value is 1 and 5, respectively) during interview schedule survey and focus group discussion. Overall standard of living of farmers was assessed on the basis of their assets holding before and after adoption of a particular technology, the value of overall standard of living ranging from 5 to 25. A sample of 34 farmers including the 10 farmers with WHSs was covered under the present study.

3. RESULTS AND DISCUSSION

Economics of Water Harvesting Based Farming System Models

The net annual income from the IFS was found highest in model P4 (₹ 1,46,500/-) followed by model P8 (₹ 84,300/-) and model P1 (₹ 28,100/-), respectively. For other farming system models, the net income was not satisfactory, as the farmers were not sincere in their effort. It was observed that by taking up poultry in the uplands and doing intensive cultivation on the bund area apart from pisiculture in the pond can substantially increase the net income from the WHS based IFS models. The huge variation in the net income/ha in different IFS models also emphasizes the role of the farmer in building a successful model.

The IRR and BCR were calculated for the model P4 in which best net income was obtained. The IRR was found as 19.6% which is almost twice the prime lending rate of Indian banks. Thus, these small water resources have given a better return in comparison to major and medium irrigation systems where the large gap between potential and utilization of water resources makes the system uneconomical. At a discount rate of 10% which is the prevalent bank lending rate, the BCR was found as 3.65. Thus, it shows that if the farmer is enterprising and sincere in his approach, the farming system models can be very successful.

Impact of Agricultural Technology Interventions

Fig. 4 shows the average level of different types of assets of the sampled farmers before and after the technological interventions. Out of the five types of assets, physical assets, financial assets and natural assets are found to be below average during pre-adoption stage with physical assets increasing considerably to come to the above average level at the post-adoption stage. Maximum improvement occurred in physical assets (increased by 78%) followed by natural asset (66%) that indicates the improvement in living condition and natural resources especially the water resources. Social, human and financial assets gains were about 21-23%. Improvement in socio-economic condition and social recognition are also reflected which results in achievement motivation leading to inculcate the entrepreneurial abilities of the farmers. The increased income motivated the farmers to invest and intervene further leading to the growth in physical and financial assets.

The change in overall standard of living of the 34 farmers is presented in Fig. 5. It can be noted from the figure that living standard of all the farmers except one farmer was below average level prior to adoption of technological packages under the project. However, with the change of farming situation, adoption of technologies helped in bringing the living standard of 10 farm families at above

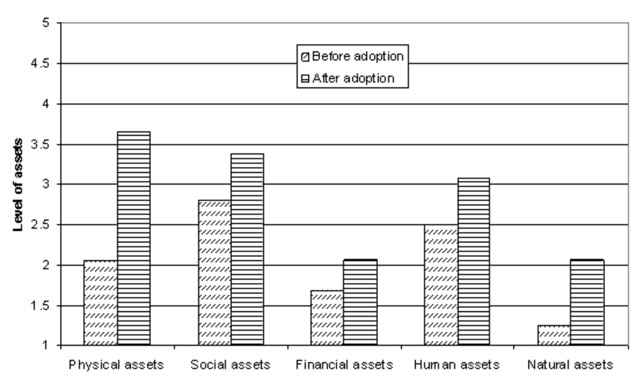

Fig. 4. Average level of different types of assets measuring livelihood of farmers

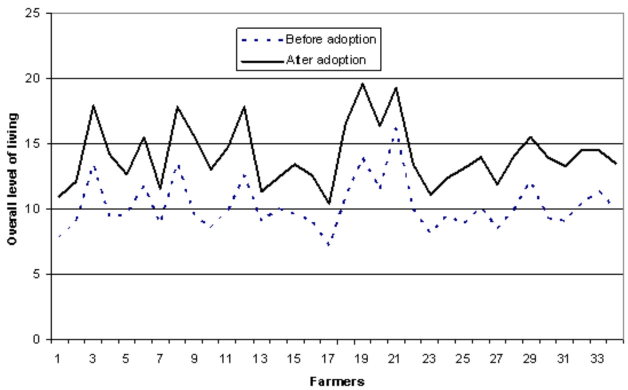

Fig. 5. Overall standard of living of selected farmers before and after adoption

average level (score >15). Standard of living of the farmers, who are engaged in short-duration fish farming / poultry farming / dairy farming besides crop farming, improved relatively better. Mean value of overall standard of living of all the 34 farmers derived through addition of the mean values of five assets, indicates that this increased from 10.24 to 14.15 (minimum and maximum possible value is 5 and 25, respectively). The minimum score increased from 7.21 to 10.43 while the maximum score increased from 16.21 to 19.57 which showed improvement in overall level of living of all the farmers due to adoption of technological options provided under the project. The change in livelihood is dependent on many factors having spatial and temporal variations. The process of change also varied from one farmer to another farmer and over the space and time. Therefore, the adoption of any technology is not exclusive but one of the factors influencing the changes in livelihood of farmers. Water resources development, crop diversification, farm sector diversification are some of the factors which lead to livelihood diversification influencing the rural economy.

4. CONCLUSIONS

The economic analysis of the multiple use of water indicated that poultry cultivation in the uplands and intensive cultivation around the embankments of the pond area is essential in improving the net return from the farming system models. The farmer needs to be very enterprising and sincere for developing a successful IFS model. The IRR and BCR of the farming system model was found as 19.6% and 3.65%, respectively. The impact analysis of the study showed that as a result of the technological introductions, there were a 78% increase in physical assets and a 66% increase in natural assets of the farmers during the study period. The overall level of living of the farmers derived through addition of the mean values of the assets, increased from 10.24 to 14.15 (on a scale of 5 to 25) in the period. The potentiality of agricultural technology interventions is reflected through the growth of overall farming system and provision of better earning and living to the small and marginal farmers of the rainfed ecosystem. Being a dynamic process, the livelihood diversification depends on many factors having spatial and temporal variations. This process of change varies from farmer to farmer and over the space and time (Ghosh *et al.*, 2011). Therefore, the adoption of any technology is not exclusive, but one of the factors influencing the changes in livelihood of farmers.

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