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IMPACT OF WATER RESOURCES DEVELOPMENT AND TECHNOLOGY INTRODUCTIONS ON LIVELIHOOD OF FARMERS IN EASTERN INDIA: A CASE STUDY†

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ABSTRACT

Agricultural technology introductions were carried out and their impact was studied in two clusters of villages in the Dhenkanal Sadar and Odapada blocks of Dhenkanal District in Odisha in the eastern Indian plateau region. Ten water-harvesting structures (WHSs) were constructed in two clusters of villages in the farmers' fields on a participatory basis. Harvested water in WHSs was used for multiple purposes, viz. agriculture, fish culture, on-dyke horticulture, vegetable cultivation, poultry, dairy and mushroom cultivation; integrated farming system (IFS) models were developed. Adequate training was also given to the farmers. The net income from the integrated farming systems varied widely between Rs. 16 100 and 251 000 ha^{-1}. Poultry farming in the uplands and intensive cultivation around the embankments of the ponds were found to be effective in increasing the net return from the IFS models. Impact analysis of the water resources development and technology introductions at the study sites was carried out by analysing the comparative position of physical, social, financial, human and natural assets of the farmers before and after adoption of the introductions. The overall standard of living of the study farmers increased from 13.5 to 17.1 on a scale of 5 to 25, respectively. Copyright © 2016 John Wiley & Sons, Ltd.

KEY WORDS: water resources development; integrated farming system; rural livelihood; impact analysis

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RÉSUMÉ

Des interventions sur la technologie agricole ont été réalisées, et leur impact a été étudié dans deux groupes de villages à Dhenkanal Sadar et Odapada, du district de Dhenkanal, en Orissa, sous le plateau de la région orientale de l'Inde. Dix systèmes de collecte d'eau (WHS) ont été construits chez des agriculteurs et sur la base du volontariat. L'eau recueillie dans WHS a été utilisée à des fins multiples comme: l'agriculture, la pisciculture, l'horticulture sur la digue, la culture des légumes, la volaille, les produits laitiers et la culture des champignons. Les modèles intégrés de système agricole (IFS) ont été développés. Les formations adéquates ont également été dispensées aux agriculteurs. Le revenu net provenant des systèmes agricoles intégrés variait considérablement entre 16 100 et 251 000 Rs ha^{-1}. Les modèles IFS montrent que l'aviculture dans les hautes terres et la culture intensive autour des digues des étangs sont efficaces dans l'augmentation du rendement net. L'analyse comparative d'impact de l'évolution des ressources en eau et les interventions technologiques sur les sites de l'étude a été faite sur des critères d'actifs physiques, sociaux, financiers, humains et environnementaux. Le niveau de vie global des agriculteurs de l'étude a augmenté de 13.5 à 17.1 dans une échelle de 5 à 25, respectivement. Copyright © 2016 John Wiley & Sons, Ltd.

MOTS CLÉS: développement des ressources en eau; système d'agriculture intégrée; moyens de subsistance en milieu rural; analyse d'impact

INTRODUCTION

Agriculture is the mainstay for the livelihood of two-thirds of the population of India, contributing nearly 16% of the national gross domestic product (GDP). The eastern region of the country is blessed with plenty of rainfall, of which about 80% occurs during the monsoon period (July to

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October). However, because of the erratic nature of the onset, distribution and ending of the rains, rain-fed ecosystems (upland, medium and lowlands) suffer the constraints of an uncertain moisture supply that results in monocropping of rice with lower production and productivity. The average cropping intensity of eastern India is about 143%, while the rice–fallow area is about 12–16 million ha due to lack of proper water resources development and management. Increasing agricultural production by bringing more area under cultivation and at the same time increasing productivity and cropping intensity would help improve the livelihood of farmers relying on rainfall. An integrated farming system approach provides better scope for multiple use of water by using the same water for several uses like agriculture, aquaculture, dairy, mushroom, poultry, ducks, etc. simultaneously within a farm (Singh and Gautam, 2002). A number of case studies on multiple-use-based integrated farming systems have been conducted in different parts of the country by simulating small and marginal farm situations (Rangaswamy *et al*., 1996; Behera and Mahapatra, 1999; Rautaray *et al*., 2005; Gill *et al*., 2009); some researchers have reported higher farm income and water productivity through this approach.

The potential of any technology lies not only in efficient utilization of resources and enhanced production but also in improving the quality of life of the farmers adopting it. A livelihood is sustainable when it maintains or enhances the assets on which the livelihood depends. Sustainable rural livelihoods are achieved through access to a range of livelihood resources (natural, economic, human, financial and social) which are combined in pursuit of different livelihood strategies, viz. agricultural intensification, livelihood diversification, migration, etc. (Scoones, 1997). 'Rural livelihoods' is a complex and wide-ranging phenomenon (Ashley *et al*., 2003) and holds the key for development of the rural economy. But very few studies have been done to assess the impact of water resources development and multiple use of water on improvement in rural livelihoods.

In view of this, a study was carried out in the plateau region of eastern India which has been classified as Agro Ecological Region (AER) No. 12 by the National Bureau of Soil Survey and Land Use Planning, Nagpur, India (Sehgal *et al*., 1992). This agro-ecological region comprises north-western and western Odisha, Chhatishgarh, Jharkhand and southern districts of West Bengal; it is characterized by a hot and moist subhumid type of climate with dry summers and mild winters. Agriculture is the major source of livelihood of the people in this region. However, agricultural productivity in the region is very low due to a lack of water resources, technical knowledge and accessibility to quality planting materials (Srivasatava *et al*., 2009). Therefore the people of the region are among the poorest in India. The study was carried out through a 'National Agriculture Innovation Project (NAIP)' in the Dhenkanal district of Odisha', eastern India. In the project, technological inputs were provided to the farmers and their impact on the livelihood of the farmers was studied. Our objectives of this case study were: (i) to develop integrated farming system models, (ii) to analyse economic returns from the technology introductions, viz. construction of water-harvesting structures, and (iii) to study the impact of water harvesting and integrated farming system models on the livelihood of farmers relying on rainfall. An innovative approach has been used in the study for impact analysis of the technological introductions.

STUDY AREA

The study was carried out in three villages (Khallibandha, Nuagaon and Mandapala) in the Dhenkanal Sadar block and three villages (Gunadei, Belpada and Kaunriapala) in the Odapada block of Dhenkanal district, Odisha, respectively (Figures 1, 2). All study villages are situated on the banks of the River Brahmani, which is a major river of Odisha state in eastern India. The total area of Khallibandha, Nuagaon and Mandapala villages is 247.26, 448.19 and 58.92 ha, respectively. These three villages are covered mostly by two river basins, i.e. Tarava and Nuagaon River basins (Figure 1). The total area of Gunadei, Belpada and Kaunriapala villages is 436.82, 191.34 and 239.40 ha, respectively. These three villages are covered by two river basins, i.e. the Gunadei and Kaunriapala River basins (Figure 2). The total area of Tarava, Nuagaon, Gunadei and Kauriapala River basins is 469.48, 540.76, 788.44 and 1066.73 ha, respectively.

The mean monthly distribution of rainfall with standard deviation for the Dhenkanal Sadar block and the Odapada block is shown in Figures 3, 4, respectively. The 35-year (1979–2013) mean annual rainfall of the Dhenkanal Sadar block is 1440 mm with a standard deviation of 328 mm, whereas the mean rainfall of the Odapada block is 1260 mm with a standard deviation of 284 mm. The bulk of the rainfall occurs during the monsoon period of June to October (86.8% of total rainfall in Dhenkanal Sadar block and 87.9% in Odapada block). Maximum mean monthly rainfall occurs in August (349 mm in Dhenkanal Sadar block and 330 mm in Odapada block), followed by July (335 mm in Dhenkanal Sadar block and 313 mm in Odapada block) and June (230 mm in Dhenkanal Sadar block and 202 mm in Odapada block), respectively.

MATERIALS AND METHODS

Technology introductions

Introduction of agricultural technologies like the construction of water-harvesting structures (WHSs), multiple use of

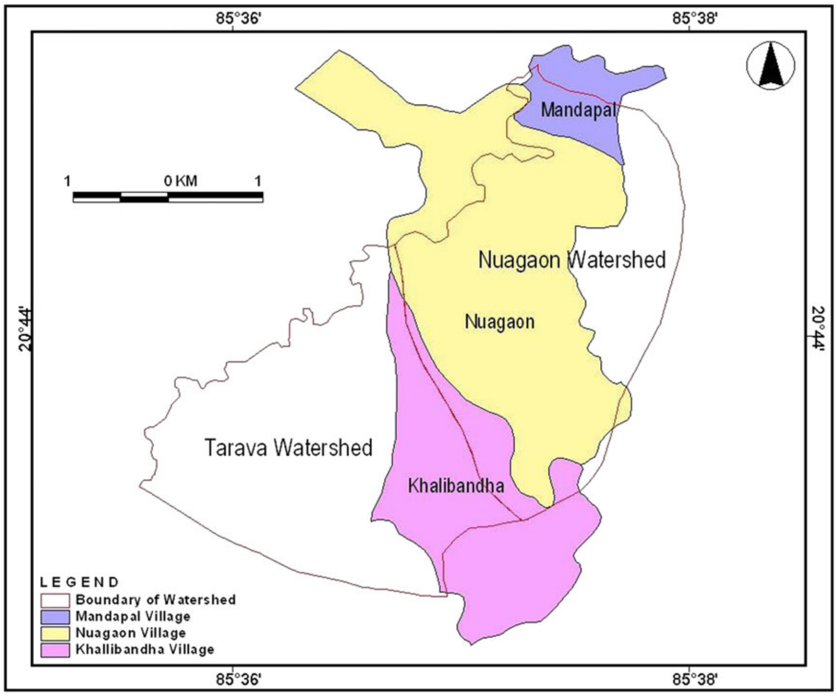

Figure 1. Study area in Dhenkanal Sadar block

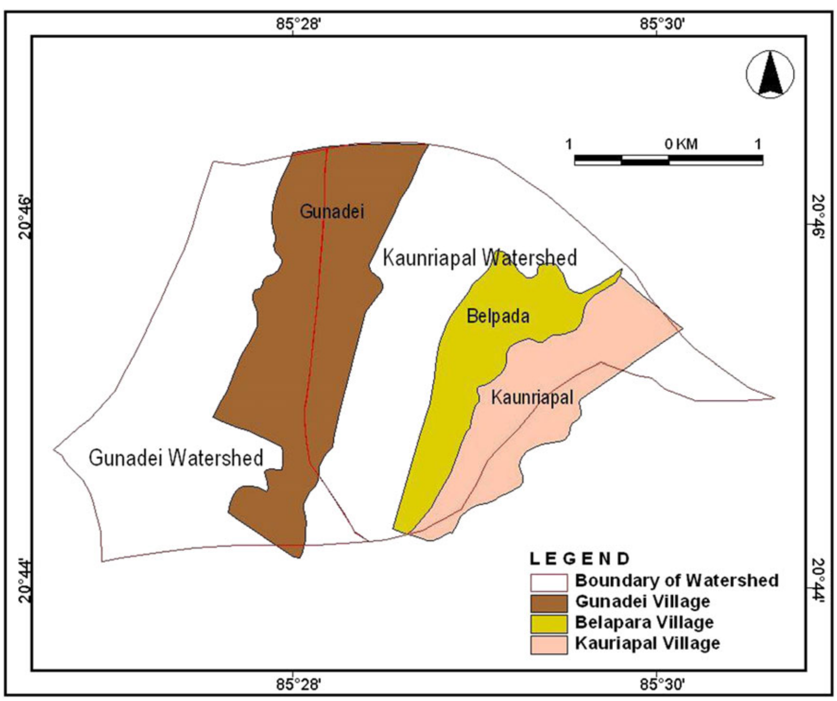

Figure 2. Study area in Odapada block

stored water in WHSs and crop diversification, was carried out in the six identified study villages over a period of 5 years from 2009–2010 to 2013–2014. Training and demonstration visits for farmers were also conducted on water management technologies. The different technology interventions are discussed as follows.

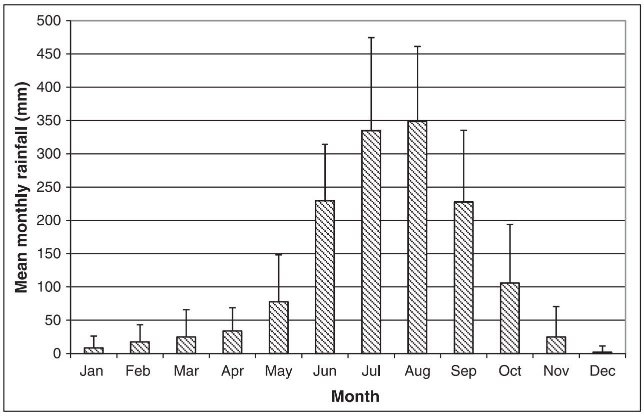

Figure 3. Monthly variation of rainfall in Dhenkanal Sadar block

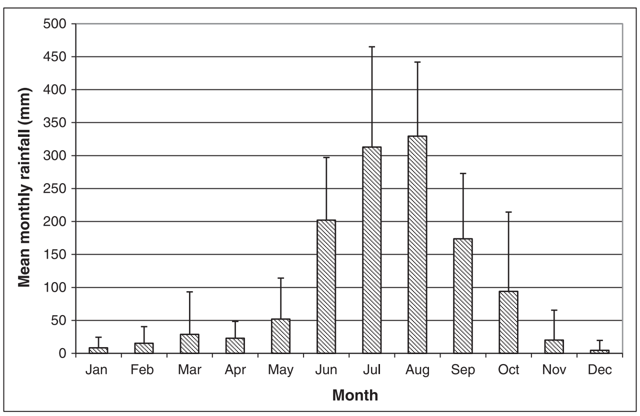

Figure 4. Monthly variation of rainfall in Odapada block

Construction of WHSs and multiple use of water

Ten WHSs distributed over six villages were constructed in the farmers' fields on a participatory basis in the year 2009–2010. The farmers agreed to meet a part of the expenditure for construction of the WHSs, i.e. construction of bunds around the ponds. Details of the 10 WHSs including the name of farmer, location and capacity of ponds are presented in Table I. The identification name of the WHSs, i.e. KLD1, KLD2, etc. has been given based on the study village in which the WHS was constructed. The volume of WHSs varies from a minimum of 200 m^3 in KLD2 and KLD3 to a maximum of 2500 m^3 in NG2. The harvested water was used for field crops, on-dyke horticulture, fish culture, poultry, dairy, mushroom and vegetable cultivation to develop them into integrated farming system (IFS) units; and this was continued for a period of 4 years (2010–2011 to 2013–2014). The WHSs were used as a source of water for agriculture and other multiple use components in the post-monsoon season, and also for supplementary irrigation to the paddy crop during dry spells in the monsoon season.

The components of the land area for the IFS units comprised pond area, embankment or bund area, upland area and cultivated paddy area. The distribution of area of different land components in different units and the system adopted in the IFS model is also shown in Table I. The percentage of paddy area was highest (34.8–79.5%) in most of the IFS units. The pond area was used for fish culture and the bund area used for on-dyke horticulture, whereas the upland area was used for dairy, poultry, mushroom and vegetable cultivation. Banana, papaya, drum stick and arhar were planted on the embankments around the ponds as on-dyke horticulture. Vegetables like potato, brinjal, ladies finger, tomato, cabbage, cauliflower, cucumber, ridge gourd, cowpea, onion and chilli were cultivated either as *kharif* (monsoon) or *rabi* (post-monsoon) vegetables.

The system adopted in the IFS unit represents the multiple-use components adopted in the model (Table I). For example, 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 them. On-dyke horticulture was undertaken by the farmers only in farming system units KLD1, NG1, MDL1, KRL1 and BLP1, whereas poultry was adopted in models KLD1, NG1 and BLP1. All multiple-use components including dairy and mushroom cultivation were only found together in farming system unit NG1.

Crop diversification

Apart from the above 10 benefitting farmers, other farmers in the study villages were encouraged into crop diversification from paddy to vegetables, pulses, fish culture and mushroom cultivation. During the study period, three farmer groups were formed in the Dhenkanal Sadar block for watermelon cultivation using river lift irrigation on the banks of River Brahmani. Pumps were provided to the farmers 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 watermelon. Two farmer groups were formed in Odapada block for vegetable cultivation by river lift irrigation. A group of farmers in Dhenkanal Sadar block carried out mushroom cultivation.

Training and demonstration visits

Six training programmes with one in each study village were conducted on advanced water management technologies

Table I. Location and volume of water-harvesting structures

Name of farmer	Village	Pond area (m^2)	Bund area (m^2)	Upland area (m^2)	Paddy area (m^2)	Total area (m^2)	Volume of WHS (m^3)	System adopted
Tapan Biswal (KLD1)	Khallibandha	300 (7.3%)	210 (5.1%)	500 (12.2%)	3 100 (75.4%)	4 110	500	rfhvp
Niranjan Biswal (KLD2)	Khallibandha	150 (4.2%)	150 (4.2%)	550 (15.5%)	2 700 (76.1%)	3 550	200	rfv
Khageswar Biswal (KLD3)	Khallibandha	150 (4.2%)	150 (4.2%)	450 (12.5%)	2 850 (79.1%)	3 600	200	rfv
Sribascha Biswal (NG1)	Nuagaon	800 (17.7%)	360 (8.0%)	1 750 (38.8%)	1 600 (35.5%)	4 510	1 500	rfhvpdm
Prafulla Biswal (NG2)	Nuagaon	1 400 (8.5%)	450 (2.8%)	1 500 (9.2%)	13 000 (79.5%)	16 350	2 500	rfv
Daktar Brahma -(MDL1)	Mandapala	400 (9.8%)	240 (5.9%)	950 (23.2%)	2 500 (61.1%)	4 090	1 000	rfhv
Surendra Prusty (KRL1)	Kaunriapala	225 (11.2%)	180 (8.9%)	510 (25.3%)	1 100 (54.6%)	2 015	350	Rfhv
Upendra Barala (BLP1)	Belpada	450 (10.8%)	270 (6.5%)	2000 (47.9%)	1 450 (34.8%)	4 170	750	Rfhvp
Ashok Barala (BLP2)	Belpada	200 (6.6%)	180 (5.9%)	950 (31.4%)	1700 (56.1%)	3 030	425	Rfv
Laxmidhara Dehury (GND1)	Gunadei	400 (9.0%)	250 (5.6%)	800 (18.0%)	3 000 (67.4%)	4 450	550	Rfv

Figures in parentheses show the percentage of land component out of the total area.
r = paddy cultivation, f = fish culture, h = on-dyke horticulture, v = vegetable cultivation, p = poultry, d = dairy, m = mushroom cultivation.

during the 4-year period. In addition, four demonstration visits were arranged for farmers from both clusters of villages to show them drip and sprinkler irrigation systems, nursery management, crop care and management system under net house, vermicomposting, organic farming and other technologies related to agriculture and water management.

Evaluation of short-duration aquaculture in WHSs

Low-input-based scientific fish culture operation was carried out for 4 consecutive years (2010–2011 to 2013–2014) in 10 WHSs as a part of multiple uses for enhancing water productivity for farmers relying on rainfall. Pond preparation such as application of lime ($CaCO_3$) @ 750 kg ha^{-1}, fresh cattle dung @ 7000 kg ha^{-1} as a basal dose and fertilizer (urea: single superphosphate 1: 1) @ 3 ppm was carried out prior to stocking of fish fingerlings. Seven days after WHS preparation (first week of August), fish fingerlings of Indian major carp (Catla catla, Labeo rohita and C. mrigala) were stocked after proper acclimatization @ 7500 fingerlings ha^{-1}. Stocking composition was 30: 30: 40. Supplemental feeding was provided with a ratio of 60: 40 (rice bran: mustard oil cake) @ 5, 4, 3 and 2% of mean body weight, twice a day, during the first, second, third and fourth month to harvesting, respectively. Periodic manuring with fresh cattle dung @ 500 kg ha^{-1} and liming @ 50 kg ha^{-1} were carried out every 15 days to maintain the plankton population in the ponds' ecosystem. Periodic observation of water quality and fish growth parameters was recorded at regular intervals at the experimental site. Major physicochemical parameters of pond water, e.g. dissolved oxygen, temperature, pH, transparency, total alkalinity, nitrite-N, nitrate-N, ammonia and total suspended solids were monitored monthly using standard methods (American Public Health Association (APHA), 1995). Consumptive water use was computed by adding the water in the harvested biomass (about 0.75 m^3 t^{-1}) with possible outflows from the pond such as evaporation, seepage, transpiration and regulated discharge (Mohanty *et al*., 2015). In the present study, transpiration loss was considered negligible as aquatic weeds were prevented from growing in and around the ponds. To evaluate the efficiency of water management, water productivity was estimated as:

Net total water productivity (NTWP = {total economic value of the produce (Rs.) − production cost (Rs.)}/total volume of water used in m^3).

Net consumptive water productivity (NCWP = {total economic value of the produce (Rs.) − production cost (Rs.)}/volume of consumptive water use in m^3.

Economic analyses of WHS-based integrated farming systems

The economic analyses of IFS units were done based on collection of data on yield, production, market price of produce and cost of cultivation of different components of multiple use of water through a questionnaire survey on the farmers. The analysis was done for two scenarios: (i) without considering the fixed cost of the system, and (ii) considering the fixed cost of the system. The annual fixed cost (AFC) included the annualized capital cost of the farming system model. AFC was calculated from the capital cost, useful life of the structures, depreciation, salvage value, maintenance cost and interest rate. Salvage value was assumed as 50% of the capital cost in case of WHSs and 10% in case of poultry and dairy sheds. Interest amount for the capital cost was calculated at a 10% annual interest rate. Depreciation was calculated by the following formula (Reddy and Ram, 1996):

$$D = \frac{C - S}{L} \tag{1}$$

where D = depreciation, C = capital cost, S = salvage value and L = useful life in years.

The gross income was calculated from the production and market price of the commodities and the net income by deducting the cost of cultivation from gross income. The net income per ha from individual land components and the entire system was estimated for every farming system model by dividing the net income by area.

Impact analysis

The impact on the farming situation of the farmers on adoption of a technology was realized through a comparison of farming components, acreage, production, cost of cultivation and gross income before and after adoption of the technology. The comparative position of the physical, social, financial, human and natural assets of the farmers was analysed considering the conditions before and after adoption of the technology introduction.

Physical assets included the type of housing conditions, sanitation, conveyance, electricity, cooking and communication facilities. Social assets 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 involve language competencies, education/literacy, management skills and mobility. Natural assets are the natural resources holdings of the farm family, viz. farm size, irrigated land, livestock holding, poultry and fish ponds. All the above-mentioned variables under 5 types of assets were measured on the basis of the responses of 10 farmers on a 5-point continuum scale (minimum and maximum value are 1 and 5, respectively) during an interview using a pre-tested survey schedule. The overall standard of living of farmers was assessed on the basis of their asset holding before and after the technology introduction, the value of overall standard of living ranging from 5 to 25. The standard of living (L_i) of the farmer adopting the technology was estimated using the following relation:

$$L_i = \sum (P_i + S_i + F_i + H_i + N_i) \tag{2}$$

where i indicates number of farmers adopted the technology =1, 2, ….., 34,

$$P_i = \frac{\sum PA_{ij}}{\sum j} \tag{3}$$

where j (= 1, 2, …) indicates parameters measuring physical assets,

$$S_i = \frac{\sum SA_{ik}}{\sum k} \tag{4}$$

where k (= 1, 2, ….) indicates parameters measuring social assets,

$$F_i = \frac{\sum FA_{il}}{\sum l} \tag{5}$$

where l (= 1, 2, ….) indicates variables measuring financial assets,

$$H_i = \frac{\sum HA_{im}}{\sum m} \tag{6}$$

where m (= 1, 2, ….) indicates variables measuring human assets and

$$N_i = \frac{\sum NA_{in}}{\sum n} \tag{7}$$

where n (= 1, 2, ….) indicates variables measuring natural assets.

RESULTS AND DISCUSSION

Performance of short-duration aquaculture in WHSs

The recorded average minimum and maximum values of various water quality parameters prevailing in the WHSs during the ongoing experimental period were: water temperature 27.1–33.8 °C; water pH 6.9–8.8; dissolved oxygen 4.5–6.9 ppm; total alkalinity 87–129 ppm; dissolved organic matter 2.6–5.6 ppm; nitrite-N 0.006–0.07 ppm; nitrate-N 0.06–0.5 ppm; ammonia 0.01–0.21 ppm; transparency 29 $\pm$ 4; and total suspended solids 197–368 ppm. TSS and dissolved oxygen concentration showed a decreasing trend with the advancement of the rearing period, while the gradual increase in nitrite, nitrate and ammonia was attributed to an increased level of metabolites and organic matter. At any given point of time, other water quality parameters did not register any specific trend. Overall crop performance (pooled data over 3 years) in terms of productivity ranged from 1.35 to 2.73 t ha^{-1} (Table II), while the net return ranged from Rs. 1460 to Rs. 11 400 per WHS. The apparent feed conversion ratio, AFCR, ranged from 1.19 to 1.48. Growth rate and biomass contribution in all the WHSs was always higher in C. catla followed by C. mrigala. Usually L. rohita grows faster than C. mrigala. However, in all the WHSs, bottom feeders (C. mrigala) registered better growth rates than the column feeder (L. rohita), probably due to their superior feed-utilizing capability and their high degree of tolerance to fluctuations of dissolved oxygen and the rich detritus food web that was maintained through periodic manuring, liming and fertilization (Mohanty *et al*., 2009, 2010). The sustainability of short-duration aquaculture in WHSs referred to both ecological and economic sustainability, which is the capacity of the production system to produce a positive income in the long run. Even if a production system scores high in terms of ecological sustainability, it will not be adopted by farmers if it does not provide sufficient income. However, the estimated net total water productivity (NTWP) of different WHSs ranged from 3.2 to 6.45 Rs. m^{-3}, while the net consumptive water productivity (NCWP) ranged from 3.95 to 8.02 Rs. m^{-3} (Table II). Higher water productivity not only reduced the need for additional water, but also minimized the operational cost. Further, water productivity is an index of the economic value of water used, a useful indicator of efficient water management that defines the relationship between crop produced and the amount of water involved in crop production.

Economics of farming system models

Table III shows the net return from different land components in the 10 IFS units, with the figures in parentheses showing the net return per ha from individual land components. The net income from a 1-ha pond area varies from a minimum of Rs. 70 300 in model NG2 to a maximum of Rs. 142 000 in model NG1, whereas the net income from a 1-ha bund area varies from a minimum of Rs. 74 100 in model BLP1 to a maximum of Rs. 319 000 in model NG1. The net income from a 1-ha upland area varies from a minimum of Rs. 41 300 in model NG2 to a maximum of Rs. 610 000 in model NG1, whereas the net income from a paddy area varies from a minimum of Rs. 15 900 in model BLP1 to a maximum of Rs. 25 400 in model NG1. It has been estimated that the net income per ha was lowest under

Table II. Performance evaluation of short-duration aquaculture in developed WHSs

IFS unit	Area (m^2)	DOC	Yield (kg)	Productivity (t ha^{-1})	Net return (Rs.)	Total water use (m^3)	Consumptive water use (m^3)	NTWP (Rs. m^{-3})	NCWP (Rs. m^{-3})
KLD1	300	180	46.0	1.53	2 390	570	435	4.19	5.49
KLD2	150	150	28.0	1.86	1 460	270	198	5.39	7.35
KLD3	150	210	29.5	1.96	1 530	300	230	5.11	6.67
NG1	800	240	219	2.73	11 400	1 760	1 420	6.45	8.02
NG2	1 400	180	189	1.35	9 850	3 080	2 490	3.2	3.95
MDL1	400	180	65.0	1.62	3 380	760	564	4.45	5.99
KRL1	225	240	48.2	2.14	2 510	495	378	5.06	6.63
BLP1	450	180	73.6	1.63	3 830	855	635	4.47	6.02
BLP2	200	150	34.5	1.72	1 790	360	272	4.98	6.59
GND1	400	180	67.8	1.69	3 530	760	580	4.64	6.08

Stocking density: 7500 fingerlings ha^{-1}, DOC: days of culture, NTWP: net total water productivity, NCWP: net consumptive water productivity. Stocking size was 38 g (*C.catla*), 28 g (*L.rohita*) and 34 g (*C.mrigala*). Stocking composition was 30% (*C.catla*): 30% (*L.rohita*): 40% (*C.mrigala*). Selling price of fish was Rs.100.00
(During the experimental period 1 USD = 55 INR.)

Table III. Per hectare net return form different land components in the IFS units

IFS unit	Net return/per hectare net return (Rs.)			
	Pond area	Bund area	Upland area	Paddy area
KLD1	2 390 (79 700)	2 200 (105 000)	28 100 (562 000)	6 200 (20 000)
KLD2	1 460 (97 100)	–	3 200 (58 200)	5 000 (18 500)
KLD3	1 530 (102 000)	–	2 900 (64 400)	4 900 (17 200)
NG1	11 400 (142 000)	11 500 (319 000)	147 000 (610 000)	4 060 (25 400)
NG2	9 850 (70 300)	–	6 200 (41 300)	32 000 (24 600)
MDL1	3 380 (84 500)	7 000 (292 000)	6 500 (68 400)	5 750 (23 000)
KRL1	2 510 (111 000)	2 750 (153 000)	2 720 (53 300)	1 880 (17 000)
BLP1	3 830 (85 000)	2 000 (74 000)	84 300 (422 000)	2 300 (15 900)
BLP2	1 790 (89 700)	–	4 400 (46 300)	3 100 (18 200)
GND1	3 530 (88 100)	–	3 450 (43 100)	5 520 (18 400)

(During the experimental period 1 USD = 55 INR.)
Figures in parentheses show the net return ha^{-1}.

paddy cultivation and highest in uplands especially where poultry was taken up as one of the components. There was a consistently higher return from poultry from a limited area especially in model NG1 which accounted for higher return from uplands, and this became much higher when it was extrapolated to net income per ha of upland area.

The net economic return per ha from the pond + bund area varied from a minimum of Rs. 47 200 in model BLP2 to a maximum of Rs. 197 000 in model NG1 (Table IV), whereas the net economic return from pond + bund + upland area varied from a minimum of Rs. 46 600 in model BLP2 to a maximum of Rs. 476 000 in model NG1. The net return per ha from pond + bund + paddy area varied from a minimum of Rs. 20 400 in model KLD3 to a maximum of Rs. 97 500 in model NG1. The net income per ha from the IFS area, i.e. the whole system without considering the fixed cost of the system, was highest in model NG1 (Rs. 336 000) followed by model BLP1 (Rs. 222 000) and model KLD1 (Rs. 94 600). It was lowest in model KLD3 (Rs. 25900) followed by model KLD2 (Rs. 27 200). The net income per ha from the IFS area was highest in model NG1 (Rs. 251 000) followed by model BLP1 (Rs. 145 000) and model KLD1 (Rs. 68 700). It was lowest in model GND1 (Rs. 16 700) followed by model BLP2 (Rs. 17 800). The analyses indicated that by taking up poultry in the uplands and doing intensive cultivation on the bund area apart from fish culture in the pond would substantially increase the net income from the WHS-based IFS models. The huge variation in net income per ha in different IFS models also emphasized the role of the farmer in building a successful model. If the farmer is enterprising and sincere in his approach, the farming system models can be successful. Even though creation of WHSs provides irrigation facilities, some farmers are not enterprising. The reasons are lack of interest in farming activities and lack of liaison with development departments of the government. However, some measures may enable

Table IV. Per hectare net return from different combination of land components

IFS unit	Net return/ha (Rs. ha^{-1})				
	Pond + bund area	Pond + bund + upland area	Pond + bund + paddy area	Total IFS area	Total IFS area considering the fixed cost
KLD1	90 000	324 000	23 000	94 600	68 700
KLD2	48 500	54 800	21 500	27 200	22 000
KLD3	51 100	59 100	20 400	25 900	20 800
NG1	197 000	476 000	97 500	336 000	251 000
NG2	53 200	47 900	28 200	29 400	18 800
MDL1	162 000	106 000	51 400	55 300	32 800
KRL1	130 000	87 200	47 400	48 900	32 900
BLP1	80 900	331 000	37 500	222 000	145 000
BLP2	47 200	46 600	23 500	30 700	17 800
GND1	54 200	4 8 100	24 800	28 100	16 700

(During the experimental period 1 USD = 55 INR.)

upscaling of the technology, such as financial support from government departments, technological support from research institutes, appropriate extension activities, timely supply of farm inputs like seeds and fertilizers, land consolidation and farm mechanization, capacity building of farmers through training and demonstrations, etc. Formation of farmer groups and development of microfinance systems should be encouraged. These key issues may be brought to the attention of policy makers for appropriate policy formulation, and horizontal spread of technology.

Impact of technological introductions

Figure 5 shows the average level of different types of assets of the 10 farmers before and after the technological introductions. Of the five types of assets, financial and natural assets were found to be below average during the pre-adoption stage, with natural assets increasing considerably to come to the above average level at the post-adoption stage (Figure 5). Maximum improvement occurred in natural assets which increased by 70%, followed by physical assets with a 24% increase. This indicates improvement in living conditions and natural resources, especially water resources. Social, human and financial asset gains were found in the range of 17–21%. Improvement in socio-economic conditions and social recognition were also apparent, which has resulted in enhancing motivation leading to encourage the entrepreneurial abilities of the farmers. Increased income has 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 10 farmers is presented in Figure 6. It is inferred from the figure that the income level of all farmers except two was below the average level (score < 15) prior to adoption of technological packages. However, with the change of farming situation,

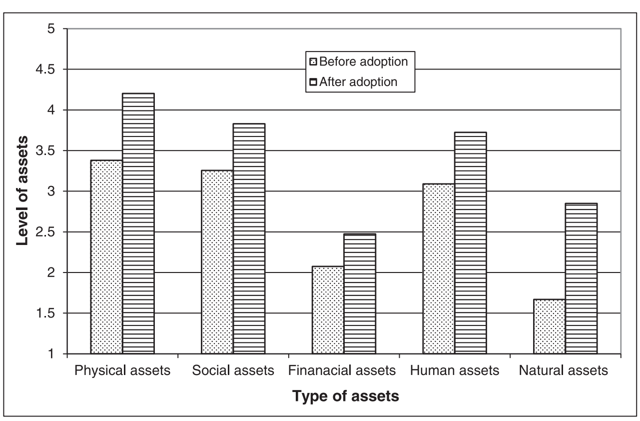

Figure 5. Average level of different types of assets measuring livelihood of farmers

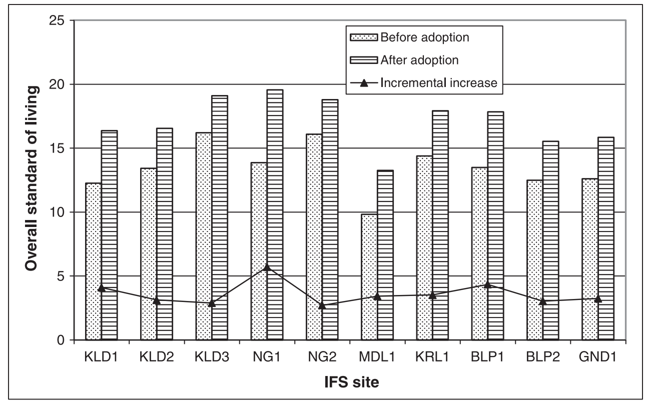

Figure 6. Overall standard of living of selected farmers before and after adoption

adoption of technologies helped to raise the living standard of all but one farm family to above average level (score > 15). The standard of living of the farmers who were engaged in more multiple-use activities in the IFS model improved relatively better. The mean value of overall standard of living of all 10 farmers, derived through addition of the mean values of five assets, indicated that this has increased from 13.5 to 17.1 (minimum and maximum possible value is 5 and 25, respectively). The minimum score increased from 9.8 to 13.3 while the maximum score increased from 16.2 to 19.1, which showed the improvement in overall standard of living of all the farmers because of the adoption of technological options. The maximum increase in standard of living of the farmers was observed in model NG1 (increase of 5.7), followed by model BLP1 (4.35) and KLD1 (4.1). It was observed that the improvement in standard of living of the farmers was in tune with the increase in net economic return from the IFS models (Table IV).

Being a dynamic process, 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 and over space and time. Therefore, the adoption of any technology is not exclusive, but just one of the factors influencing changes in livelihood of farmers. Water resources development, crop diversification and farm sector diversification lead to livelihood diversification influencing the rural economy; therefore, adoption of appropriate agricultural technology in an IFS approach holds the key for development of rural economies (Mehta, 2009).

CONCLUSIONS

The present study elucidates the effect of water resources development, multiple use of water and other technological interventions on the livelihood of farmers who rely on rainfall in eastern India. The economic analysis of multiple use of water from WHSs showed that there is a potential of net farm income upto Rs. 250 000 ha^{-1}. The analyses indicated that poultry farming in the uplands and intensive crop cultivation around the embankments of ponds are essential in improving the net return from the farming system models. The impact analysis of the study showed that as a result of the technological introductions, there was a 70% increase in natural assets and a 24% increase in physical assets of the farmers during the study period. The overall standard of living of the farmers derived through addition of the mean values of the assets indicated that this increased from a score of 13.5 to 17.1 (on a scale of 5 to 25) in the period. Even though creation of WHSs provided irrigation facilities for all the farmers, there was a substantial gap in the net income of different farmers. This can be attributed to the fact that to develop a successful IFS model, a farmer needs to be very enterprising and sincere. Financial support from government departments, technological support from research institutes and extension agencies, timely supply of farm inputs, land consolidation, farm mechanization and capacity building of farmers are required for upscaling of the technologies and to motivate the farmers to be more enterprising.

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