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Technological Capital and Sustainable Livelihood: Does Technological Capital of Watershed Influence Sustainable Livelihood?

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This study examines whether technological capital influences livelihood of people in watersheds. Data were collected from 130 watersheds of Orissa (India). Information on dimensions of technological capital and sustainable livelihood was collected using interview schedules and questionnaires. Measures of economic, psychological, social and ecological sustainability assessed sustainable livelihood. Technological capital was assessed on adequacy, professional support, understanding of measures and land use. Results suggest that better technological capital improves sustainable livelihood in the watershed. Understanding of measures increases economic well-being of people, better land use enhances psychological well-being of people and professional support promotes social equity among people. Adequacy of measures, understanding of measures, adequacy of professional support and better use of land improve ecological upkeep of the watershed. Understanding of measures, land use and professional support received are critical technological parameters for influencing more than one sustainability dimension. Ecological sustainability of the watershed enhances psychological well-being of people.

Introduction

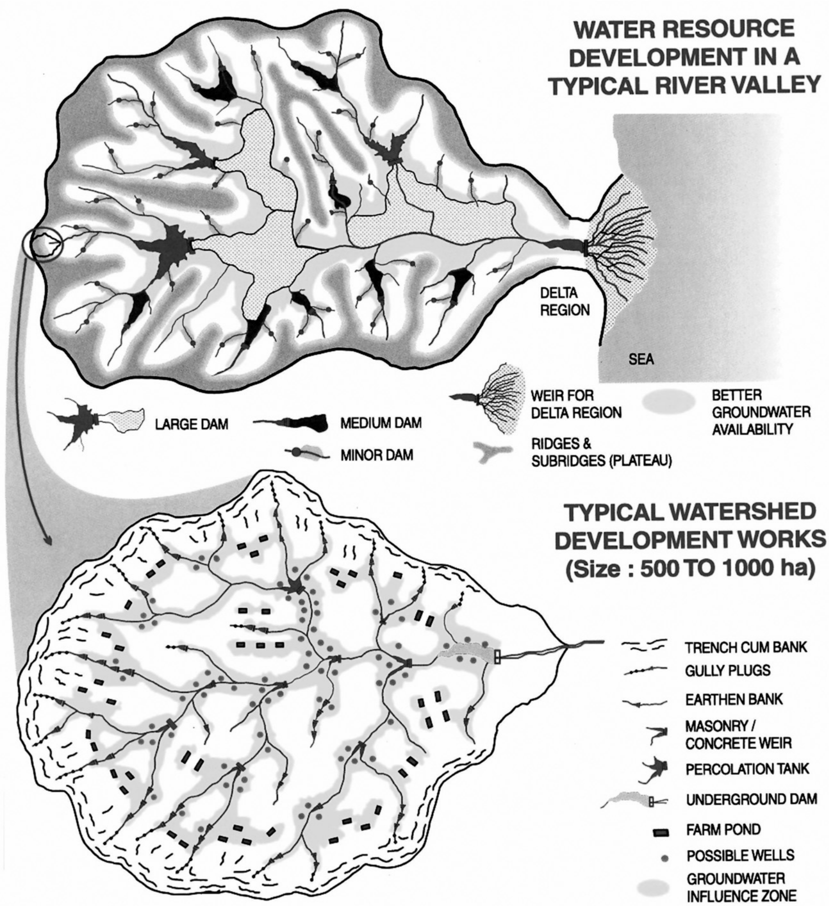
In India, there is much dependency on the rain-fed areas for food, fodder and fibre because irrigated command is a small proportion of total arable area. But the needs can not be met at the cost of environment by converting more lands into agricultural use, because environmental conservation is also required. Attempts made to develop rain-fed areas through catchments treatment and techno-centric programmes failed due to independent focus on resource conservation, crop production, crop diversification, employment generation, drought mitigation and flood moderation rather than livelihood integration of local people. Livelihood in rain-fed areas is derived from sources of agriculture, allied activities and natural resources. Therefore, comprehensive approach of watershed development and management (WDM) has been prioritized to improve livelihood of people through eco-friendly rain-fed agriculture, allied activities and sustainable natural resource utilisation practices (Achouri 2006; Reddy et al. 2004; Yoganand and Gebremedhin 2006).

However, WDM in India with the objectives of improving livelihood of people and natural resource conservation, has not yet been successful in addressing either. It is due to lack of focus on sustainable livelihood of people, which speaks of development of current livelihood by keeping natural-resource base intact for future use. Further, few publicized watersheds like Sukhomajri in Haryana, Kuppam in Andhra Pradesh and Ralegan Siddhi in Maharashtra have features of strong administrative back-up, favourable topography, homogeneous social structure, typical market demand and charismatic leadership that are hardly replicable at other places (Chopra et al.1988; Pangare and Pangare1991; Sastry et al. 2002). Moreover, common processes of technology adoption and absorption across watersheds, responsible for developing, using and maintaining natural resources for livelihood have not been accorded due importance.

Watersheds in this context mean micro watersheds. A micro watershed (500–1000 ha) is a manageable bio-physical unit for integrated use, regulation and treatment of water and land resources (Swallow et al. 2001) from which all water drains through a common point (Figure 1). Land, water, flora, fauna and people within the area form the resource base of the watershed. The annual allocation exceeding 1,000 million US$ on WDM indicates the thrust of Government of India on this sector. However, routine monitoring and control during the programme is limited to physical and financial achievements. The absence of statutory evaluation after withdrawal of project implementing agencies (PIAs) has kept success of WDM in dark (Sharma 2005). Thus, identification of generalized success indicators and antecedents is warranted.

In earlier studies on WDMs, performance has been viewed from isolated outcomes like improvement in yield, crop diversification, natural resource conservation and so on. Of late, livelihoods comprising land and non-land based activities have been recognized as performance indicators of watersheds (DFID 2000). Moreover, sustainability of livelihood comprising of current livelihood, with an assurance of future livelihood, would be a better measure of success of

Figure 1
Schematic Diagram of a Typical Watershed



Note: All hypothesized relationships indicate positive/ direct impact.

watersheds. The thrust of government also warrants identification antecedents of success so that pre-emptive measures can be taken for replication. Earlier studies show adoption of economically viable, ecologically compatible and socially acceptable technology influence success of watersheds in meeting livelihood (Fujisaka 1989; Kerr et al. 1996; Verbist et al. 2005). While economically viable technology gives faster and better return on investments, ecologically compatible technology utilizes natural resources without making its future availability bleak. Socially acceptable technology makes users comfortable with it.

Sustainable Livelihood

Livelihood means meeting current needs. Whereas, sustainability of livelihood is achieved when current needs are met with a promise to fulfil future needs as well. In programmes like WDM, natural resources being the source of livelihood are nurtured to provide livelihood now and also in future. Sustainability of development in rural areas needs to ensure sustainability of livelihood (Ghai 1994; Lele 1991; UNCED 1992). Sustainable livelihood construct, evolved through interactions of research, policy and practice has been a widely accepted pragmatic outcome indicator of rural development activities, because it can be discussed, observed, described and quantified (Carney 2002; Chambers and Conway 1992; FAO 2000; Rennie and Singh 1996; Soussan et al. 2000). Therefore, it is appropriate to evaluate success of WDM from the extent to which it addresses sustainability of livelihood.

Watershed development and management has economic, social and environmental impacts on livelihood (Sharma et al. 2005). Developmental initiatives like WDM can better succeed with well-being of people. Thus, livelihood sustainability can be conceptualized on dimensions of: (*i*) economic, (*ii*) ecological, (*iii*) social and (*iv*) psychological. In past, economic, social and ecological sustainability have rarely been addressed simultaneously (Mahdi et al. 2008; Prasad and Kant 2003). Psychological sustainability consists of further enriching the construct because of inclusion of subjective well-being of people, along with other objective measures of sustainability. Economic and psychological sustainability corroborates sustainability of households. Community sustainability is encompassed in social sustainability while sustainability at watershed level is envisioned within ecological sustainability.

Economic sustainability can be determined on need-fulfilling capacity of households. Psychological sustainability can be evaluated on subjective well-being of households (Buss 2000). Social sustainability can be assessed on resource caring and sharing practices in the community. Ecological sustainability can be gauged on natural resources improvement and eco-friendly livelihood activities development.

Economic sustenance of households, in terms of meeting their needs, restrain people against degradation of environment for livelihood. Psychological well-being of beneficiaries enhances motivation towards WDM activities. Social sustainability, equity in sharing of costs and benefits within the community fosters participation for common purpose and vice-versa (Kerr et al. 2007). It is governed by access to resources, physical and mental abilities and livelihood—articulating the processes that keep people functioning (Leach et al. 1999). Ecological sustainability, meeting current livelihoods and keeping resource base intact for future livelihoods make people confident on functioning of WDM (Carney 2002).

Therefore, it is suggested that economic, social and psychological sustainability would depend on ecological sustainability.

Sustainability is a longitudinal temporal phenomenon. However, one time measures can indicate the trend through post WDM changes. In watersheds, quantity and quality of services flowing from natural, social, human, physical and financial capital determine livelihood sustainability (Bourdieu 1986; Carney 2002; Pretty and Ward 2001).

Technological Capital

Watershed technology needs to manage land, water and forest resources for providing sustainable livelihood to people (Perez and Tschinkel 2003). Watershed technology is of two categories: (*i*) agronomic and (*ii*) engineering measures. Agronomic measures are contour trench/ bund/ vegetative hedge, bench terracing, field bunding/ land development work, mulching, plantation and so on. These measures are usually adopted in upper reaches for *in situ* moisture conservation, groundwater recharge, better land use and soil conservation. Engineering measures have structural components like water harvesting structure, farm pond, diversion weir, loose boulder structure, check dam, percolation tank, sunken pond, dug well, and so on. These measures are executed generally in lower reaches for arresting runoff water, checking soil erosion and exploitation of recharged groundwater. People place more importance on water retention than soil conservation for better agricultural practices. Agronomic and engineering measures conforming to bio-physical characteristics of watersheds are responsible for sustaining livelihoods.

The insights from exposures of watersheds in the states of Andhra Pradesh, Gujarat, Maharashtra and Orissa and earlier literatures suggest technological parameters of (*i*) adequacy of measures, (*ii*) sequencing of measures, (*iii*) professional support received, (*iv*) understanding of measures, (*v*) land use, (vi) maintenance arrangement and (*vii*) professional bias to be critical in sustaining livelihoods. Technological parameters can be an antecedent for success of WDM. It includes physical capital. The economic connotation of capital in place of parameters suits the purpose because technology is a factor of production for livelihood in the watershed. Technological capital can be broadly grouped into technology adoption and technology absorption.

Technology adoption in watersheds depends upon the bio-physical characteristics of the watershed, need of users and implementation priorities. Technology adoption constitutes of adequacy of measures, sequencing of measures and professional bias. Technically, the key to success lies in adequacy and appropriateness of measures matching to hydrological regime of the watershed. The treatment sequence strictly from ridge to valley as per recommendation of Hanumantha Rao Committee (Turton et al. 1998) seems at times unworkable considering accessibility to the spot. More often, it is necessary to initiate some activities in the lower reaches for gaining confidence of beneficiaries. Therefore, sequencing of treatments more on ridge than on valley is a practical proposition. Professional incompetence and bias of PIAs towards specific measures seem critical at times. Irregular fund allocation and time constraints induce going for attractive structures instead of beneficial ones.

Absorption of technology by beneficiaries is also critical in determining livelihood sustainability in watersheds (McDonald and Brown 2000). Technology absorption comprises of understanding the utility of measures by beneficiaries, maintenance arrangement, professional/ departmental support received for agriculture and allied activities, technology, organisation and so on along with better land use practices. A better understanding of measures fosters taking greater advantage of treatments. Preventative maintenance by collective effort of beneficiaries helps in enhancing the life of measures. Professional support on agriculture, technical know-how of treatments, animal husbandry, rural development and institution building motivates people towards WDM activities (Farrington and Lobo 1997), while increase and diversification in land use on agriculture, horticulture, agro-forestry and forestry enhances livelihood opportunities.

Adequacy of measures improves economy of households by offering enough means to livelihood. Natural resource conservation of the watershed is better attained with adequacy of measures because present needs are taken care of without staking its future availability. Professional support fosters caring and sharing of WDM due to development of confidence among people, thereby helping them to come forward to cooperate with each other. It also provides technical know-how for better ecological upkeep. Better understanding of utility of measures increases economic sustenance due to beneficiaries' improved awareness in taking better advantage of measures. An understanding of measures also inculcates sustainable natural-resource utilization practices in people, as they intend to derive benefits perpetually. Psychological well-being of people increases with better land use practices due to assertiveness of people about continuance of benefits in future. Improved land use practices enhance ecological sustainability of the watershed through maintaining bio-physical equilibrium.

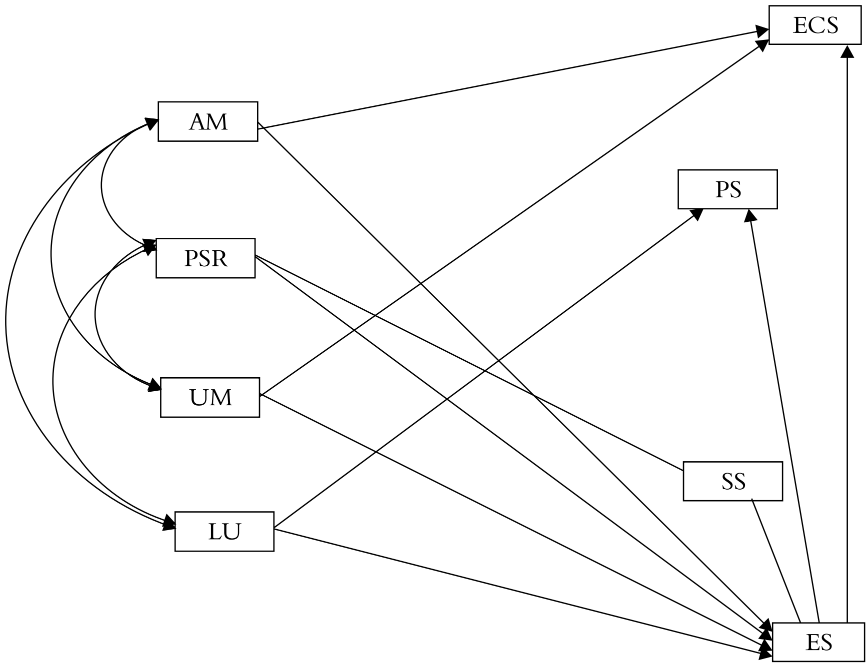
Besides the direct impacts, the closely related dimensions of technological capital also have indirect impacts on livelihood sustainability. Adequacy of measures and professional support are complementary to each other. The adequacy of measures creates motivation in beneficiaries for understanding utility of measures due to their confidence on WDM to fulfil everyone's need. Adequacy of measures ensures serviceable capacity fostering and increased and diversified eco-friendly land use practices. Professional support improves understanding of measures and land use.

The proposed hypothesis emerging out of the above discussions is:

H1: The better the dimensions of technological capital of the watershed, the better will be the beneficiaries' livelihood.

The proposition for investigation is shown figuratively (Figure 2).

Figure 2
The Proposed Model with Hypothesized Relationships



Notes: AM = Adequacy of measures, PSR = Professional support received, UM = Understanding of measures, LU = Land use, ECS = economic sustainability, PS = Psychological sustainability, SS = Social sustainability, ES = Ecological sustainability.

METHOD

Primary and secondary data were collected from beneficiaries and PIAs of watersheds in Orissa (India). The data were collected through interview schedules from beneficiaries and questionnaires from PIAs. The data were obtained on four variables from beneficiaries only, three variables from beneficiaries and

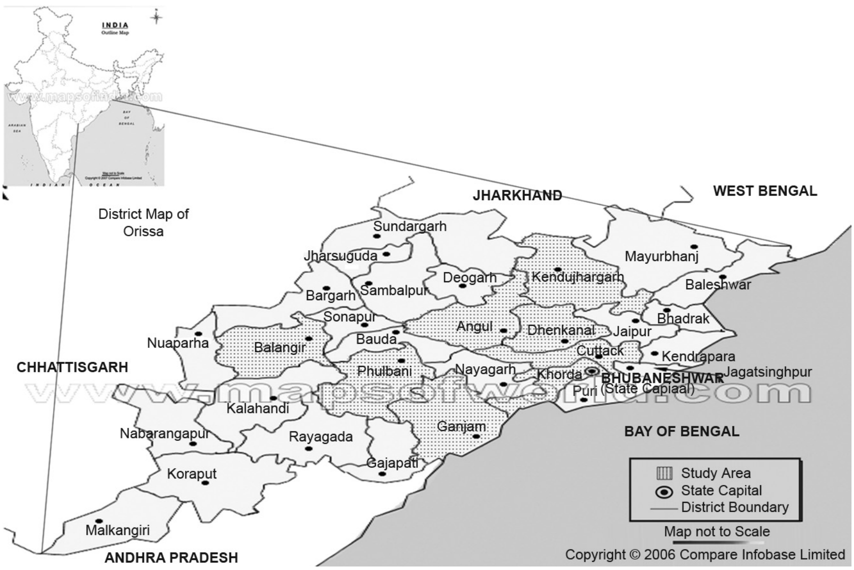
PIAs and one variable from PIAs only. The additive scores on items of a variable procured from beneficiaries were averaged for the watershed. Averaged scores on items obtained from beneficiaries were added to scores on other items procured from PIAs to find the total score of the variable. Total score of each variable was then divided by total number of items comprising of beneficiaries and PIAs for retaining the score within the scale range.

Sample

Watersheds

The 130 (11 per cent) watersheds out of total 1,170 were studied from one district of poverty-stricken Kalahandi-Bolangir-Koraput (KBK) districts and seven non-KBK districts of Orissa. The study area (Figure 3) had covered the two agro-climatic zones of the state out of 15 in India. Anugul, Bolangir, Dhenkanal, Kandhamal and Keonjhar districts come under zone number 7, the eastern plateau and hilly region. Cuttack, Ganjam and Khurda districts come under zone number 11, the east coast plains and hilly region. The selection at district level

Figure 3
Study Area of Watersheds



Source: www.mapsofindia.com.

was made at random from the list of watersheds more than two years old with the consideration of approachability to the site.

The profile of surveyed watersheds is shown in Table 1. The survey of watersheds were carried out in eight (out of 30) districts and 45 (out of 314) blocks of the state. The study had covered watersheds under Drought Prone Area Programme (DPAP), Integrated Watershed Development Programme (IWDP) and Employment Assurance Scheme (EAS) of the Ministry of Rural Development (MoRD), National Watershed Development Programme for Rain-fed Agriculture (NWDPRA) of the Ministry of Agriculture (MoA) and Western Orissa Rural Livelihood Programme (WORLP) of DFID. Where watersheds in a district were more, lesser proportion of watersheds was studied and the converse was true for districts having less number of watersheds.

Respondents

Data were collected from five households in each watershed. Marginal and landless households being vulnerable to livelihood sustainability were mostly selected. Households of ordinary beneficiaries were contacted keeping aside households of watershed council/committee members to elicit unbiased response.

Of the 650 respondents interviewed, 98.8 per cent were males and 1.2 per cent were females. Males outnumbered the females because females did not come out

Table 1
Profile of Surveyed Watershed

		Scheme Wise Surveyed Watersheds[a]					
District	*Total Watersheds*	*DPAP*	*EAS*	*IWDP*	*NWDPRA*	*WORLP*	*Total Surveyed (%)*
Anugul	45	–	–	9	5	–	14 (31)
Bolangir	515	–	5	4	2	20	31 (6)
Cuttack	34	–	–	4	–	–	4 (12)
Dhenkanal	118	12	–	–	1	–	13 (11)
Ganjam	41	–	–	8	11	–	19 (46)
Kandhamal	326	18	–	–	3	–	21 (6)
Keonjhar	53	–	–	9	3	–	12 (23)
Khurda	38	–	–	11	5	–	16 (42)
Total	1170	30	5	45	30	20	130 (11)

Notes: [a]DPAP = Drought Prone Area Programme, EAS = Employment Assurance Scheme, IWDP = Integrated Watershed Development Programme, NWDPRA = National Watershed Development Programme for Rain-fed Agriculture, WORLP = Western Orissa Rural Livelihood Programme.

in presence of male members of the family. The average age of the respondents was 44 with maximum of 84 and minimum 18 years. Of the respondents, 9.5 per cent were illiterate, 10.2 per cent were informally literate, 31.4 per cent had education up to primary level, 38.9 per cent up to secondary level, 9.7 per cent up to graduation level and only 0.3 per cent had education above graduation level. The average family size was 6 with maximum 17 and minimum 1 member. The beneficiaries were mostly marginal farmers including landless (land holding less than 1 ha; 89.2 per cent), and a few were small (land holding 1–2 ha; 8.5 per cent) and large (land holding more than 2 ha; 2.3 per cent) farmers (Table 2).

Table 2
Respondents' Profile

Variables	*Specification*	*Descriptives*
Sex	M (%)	642 (98.8)
	F (%)	8 (1.2)
Age	*M (SD)*	44.41 (12.94)
Literacy	Illiterate (%)	62 (9.5)
	literate (%)	66 (10.2)
	Up-to primary (%)	204 (31.4)
	Up-to secondary (%)	253 (38.9)
	Up-to graduation (%)	63 (9.7)
	Above graduation (%)	2 (0.3)
Family size	*M* (*SD*)	6 (2.52)
Beneficiary status	Marginal (%)	580 (89.2)
	Small (%)	55 (8.5)
	Large (%)	15 (2.3)

Measures

Sustainable livelihood

Sustainable livelihood was assessed through economic, psychological, social and ecological sustainability.

Economic sustainability. Economic sustainability of household assessed from respondent's last year household income and expenditures. The income data were procured on income from agriculture, forest products, animal husbandry, trading and business, service, labour and other sources. The total local value of harvest from agriculture, animal husbandry and forest products were also taken. Expenditures were procured on food, cloth, shelter, health care, education, marriage and other social functions, loan repayment, inputs for livelihood activities (seeds, fertilizer, insecticides, pesticides, agricultural implements and others) and investments in livelihood assets (land, farm pond, dug well, agricultural pump sets, agricultural equipments, improved breed of animals and others). The income and expenses in the form of cash and kind were converted to cash only. The households unable to meet basic needs on food, cloth and shelter from income were very poor in economic sustainability (score = 1). Households, which were able to meet basic expenses but unable to meet expenses on inputs for livelihood activities, including health care (personal labour being a factor of production) were poor in economic sustainability (score = 2). Households able to meet basic needs and inputs for livelihood activities, but unable to meet social payments on education, marriages and other social functions, along with loan repayments, were fair in economic sustainability (score = 3). Households able to meet expenses on basic needs, inputs for livelihood activities and social payment, but unable to meet expenses on investment on livelihood assets were good in economic sustainability (score = 4). Households meeting all their expenses from income, including investment for livelihood assets were very good in economic sustainability (score = 5). Household deficits were met from bank and local loans. Two items assessed were (*i*) household surpluses and (*ii*) economic well-being of the community due to WDM. The data on the two items were collected using visual measures. The respondents was asked to fill up a transparent glass jar with water, marked with five levels indicating: 'very poor' = 1, 'poor' = 2, 'fair' = 3, 'good' = 4 and 'very good' = 5. The Pearson correlation between above-stated five economic categories and the two visual items were 0.63 ($p < .001$) and 0.32 ($p < .01$) respectively indicated inter-item consistency in assessing economic sustainability. Higher average score on income–expenditure and two visual items indicated better economic sustainability.

Psychological sustainability. Psychological sustainability was assessed on five-item scale of Diener et al. (1985). The item contents were modified to suit the cultural context. The item contents dealt with: (*i*) life closer to ideal, (*ii*) excellent life conditions, (*iii*) satisfactions with life, (*iv*) accomplishment of desire and (*v*) expectation on positive future change. A ladder was drawn on a cardboard with four rungs. It was shown to each respondent marked with numbers 1 to 4. Each respondent was asked to place a pebble on the rungs for each item describing his/her choice indicating: 'disagree' = 1, 'slightly agree' = 2, 'fairly agree' = 3 and 'strongly agree' = 4 (Cronbach alpha = 0.77). Higher average score on items indicated better psychological sustainability.

Social sustainability. Social sustainability was evaluated on five items using a checklist (yes = 1 and no = 0). Respondents replied to three items related to: landholding-based (*i*) cost and (*ii*) benefit distribution for the treatment area and (*iii*) satisfaction among upstream and downstream users. PIAs were asked on the satisfactory levels of (*iv*) general economy and (*v*) social cohesion of the area (Cronbach alpha = 0.28). Items used were causal indicators, therefore, lend low reliability. Higher average score of five items indicated better social sustainability.

Ecological sustainability. Ecological sustainability was assessed from respondents on 22 items. The items covered: *(i)* micro environmental parameters—(a) temperature, (b) tree coverage, (c) soil erosion, (d) water quantity, (e) water quality, (f) groundwater table, (g) rainfall, (*ii*) agricultural factors—(h) land productivity, (i) irrigated area, (j) crop variety, (*iii*) animal husbandry—(k) cattle, (l) goat, sheep and pig, (m) poultry and duckery, (n) pisciculture, (o) apiary, (*iv*) land use practices—(p) floriculture, (q) horticulture, (r) agro-forestry, (s) medicinal plants, (t) forestry, (u) dedicated pasture and (*v*) diversifications of livelihood into animal husbandry and better land use practices. Two items on temperature and soil erosion were reverse keyed. Four wooden blocks—two of equal sizes, one taller and another shorter—were used for eliciting responses. Excepting for non-existent items, one of the equal blocks was kept as WDM before situation for each item. The respondent was asked to mark the WDM after situation with the help of other three blocks symbolizing no change, increase and decrease. The response against each item was recorded on a four-point rating: 'non existent' = 0, 'decreased' = 1, 'no change' = 2, and 'increased' = 3. Higher average score on items indicated better ecological sustainability.

Technological capital

Technological capital was evaluated on four parameters—(*i*) adequacy of measures, (*ii*) professional support received, (*iii*) understanding of measures and (*iv*) land use. The parameters of sequence of measures, maintenance arrangement and professional bias were not taken for analysis due to absence of variability in such data. In all surveyed watersheds, sequence of measures more from ridge than valley had been adopted. As most surveyed watersheds were in the development stage, maintenance requirement had not come up yet appreciably. However, users had shown interest towards collective maintenance. Professional bias towards engineering measures was common in all the surveyed watersheds.

Adequacy of measures. Adequacy of measures was assessed on three items from respondents and 23 items from PIAs. Three items were on: irrigation adequacy for (*i*) *kharif*, (*ii*) *rabi* and (*iii*) summer crops. Four-point rating for the items was: 'not at all' = 0, 'inadequate' = 1, 'manageable' = 2 and 'adequate' = 3 to assess the items. Moreover, most of the surveyed watersheds being in the formative stage was yet to acquire adequacy and stabilization of measures. Out of 23 items of PIAs, 19 were on adequacy of (*i*) agronomic measures—(a) contour bund, (b) contour trench, (c) field bunding, (d) plantation in compact patch, (e) backyard plantation, (f) contour vegetative hedge, (g) run-off management system,

(h) vegetative filter and (i) compost pit, (ii) engineering measures—(j) diversion weir, (k) masonry check dam, (l) earthen check dam, (m) loose boulder structures including loose boulder cross drainage, (n) percolation tank, (o) gully control structure, (p) water harvesting structure, (q) farm pond and (r) dug well and (s) for any other site-specific measure. These were assessed on extent of availability of the measure against opportunity for such measure as 'inadequate' = less than 50 per cent, 'moderately adequate' = between 50–75 per cent and 'adequate' = more than 75 per cent. Accordingly, the rating was: 'no such measure' = 0, 'inadequate' = 1, 'moderately adequate' = 2 and 'adequate' = 3. Three items evaluated the percentage of actual area irrigated during (20) *kharif*, (21) *rabi* and (22) summer. The ratings were as follows: for *kharif* less than 10 per cent = 0, 10–30 per cent = 1, 31–50 per cent = 2 and more than 50 per cent = 3, for *rabi* less than 5 per cent = 0, 5–15 per cent = 1, 16–25 per cent = 2 and more than 25 per cent = 3 and for summer less than 3 per cent = 0, 3–8 per cent = 1, 9–13 per cent = 2, and more than 13 per cent = 3. There were different ratings for *kharif*, *rabi* and summer, keeping in view reducing water balance in respective seasons. The rating for 23 item on increase in groundwater table was: no increase = 0, less than 1m = 1, 1–2m = 2 and more than 2m = 3. All the ratings were arrived during the pilot study based on information of field experts and beneficiaries. Higher average score on items indicated better adequacy of measures.

Professional support received. Professional support received was evaluated based on six items from respondents and four items from PIAs. The professional support received was gauged in the context of: (*i*) agriculture, (*ii*) engineering, (*iii*) rural development, *(iv)* animal husbandry, (*v*) organizing people and (*vi*) maintenance of account and record. Rating for the items was: 'no support' = 0, 'partial support' = 1, 'substantial support' = 2 and 'full support' = 3. Its cronbach alpha was 0.58 without items 3 and 4. Respondents considered animal husbandry as a part of agriculture. Rural development supports were non-existent in all watersheds. The items used were causal indicators, therefore, lend low reliability. PIAs responded to an item on frequency of visit of technical support team including PIA and staff to the watershed. The frequency of visits designated was as follows: more than 4 times a month = 'frequently', 2 to 4 times a month = 'sometimes', less than 2 times a month = 'rarely' and no visit = 'never'. Accordingly, the rating was 'frequently' = 3, 'sometimes' = 2, 'rarely' = 1, and 'never' = 0. The remaining three items assessed the adequacy of training provided to (*i*) PIA and staff, (*ii*) self-help groups and (*iii*) user groups. Four-point rating for these items was: 'adequate' = 3, 'moderately adequate' = 2, 'inadequate' = 1, 'no training' = 0. The ratings were developed in consultation with experts and beneficiaries during the pilot study. Higher average score on items indicated better professional support received for watershed-based activities.

Understanding of measures. Understanding of utility of measures was assessed from respondents on 10 items. Items contained engineering and agronomic measures: (*i*) masonry and earthen check dams, (*ii*) diversion weir, (*iii*) drainage line treatment with loose boulder cross drainage and loose boulder gully control structures, (*iv*) water harvesting structure, (*v*) farm pond, (*vi*) dug well, (*vii*) percolation tank, (*viii*) contour bunding, trenching and field bunding, (*ix*) run-off management system and (*x*) plantation in compact patch, backyard plantation, contour vegetative hedge, vegetative filter and compost pit. Four-point scale for the items was as follows: 'no such measure' = 0, 'no understanding' = 1, 'partial understanding' = 2, and 'complete understanding' = 3 (Cronbach alpha = 0.51). Items used were causal indicators, therefore, lend low reliability. Higher average score on items indicated better understanding of measures by beneficiaries.

Land use. Land use was evaluated on five items. PIAs were asked on change in land use due to WDM in: (*i*) agriculture, (*ii*) horticulture, (*iii*) agro-forestry, (*iv*) forestry and (*v*) barren. The rating for all items excepting barren was as follows: no increase = 0, increase within 10 per cent = 1, increase between 10–30 per cent = 2, and increase of more than 30 per cent = 3 and for barren no decrease = 0, decrease within 10 per cent = 1, decrease between 10–30 per cent = 2 and decrease of more than 30 per cent = 3. The ratings were developed in consultation with experts and beneficiaries during the pilot study. Higher average score on items indicated better land use practices.

Procedure

The survey work was undertaken from March, 2007 to March, 2008. The interview schedule was pre-tested in five watersheds of Balangir district to gauge appropriateness of wordings, duplication of responses and redundancy of items and usefulness of visual tools. Items on psychological sustainability were jumbled up in a non-sequential manner to avoid stereotyping the responses. Interview schedule in English was translated to vernacular and re-translated to English by two dual language experts to check accuracy of item contents. In early hours of the day, informal discussions were held with beneficiaries and PIAs during audio-visual documentations of watersheds. In the process, an acquaintance was made with the bio-physical characteristics of watersheds and rapport with beneficiaries was developed. Verbal and visual responses to questions were taken personally from the adult members of households in the afternoon.

At district level, PIAs and their staff were briefed on items of the questionnaire. Then after a fortnight, they were contacted for ambiguity on any items and clarified on those items. The filled-in questionnaires were then collected from PIAs. About 85 sites were accessed by hired four wheelers, 33 by two wheelers, and 12 by walk. The personal visit, observation, and interactions with beneficiaries and PIAs provided insights about lives and livelihoods of people.

RESULTS

Pearson correlations among the variables were estimated to indicate the hypothesized relationships (Table 3). The four dimensions of livelihood sustainability were related positively with one another. However, social sustainability did not relate with economic and psychological sustainability. Adequacy and understanding of measures improved economic well-being of people. Psychological sustainability increased with adequacy of measures, understanding of measures and better land use. Better professional support and understanding of measures fostered social sustainability. Adequacy of measures, understanding of measures, professional support from line departments and better land use increased ecological sustainability.

Table 3
Descriptive Statistics and Pearson Correlation among Studied Variables

Variable[a]	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. ECS	1.00							
2. PS	.18*	1.00						
3. SS	.13	–.01	1.00					
4. ES	.31***	.48***	.18*	1.00				
5. AM	.23**	.20*	.27**	.41***	1.00			
6. PSR	.09	–.08	.45***	.28**	.28***	1.00		
7. UM	.58***	.18*	.18*	.39***	.40***	.18*	1.00	
8. LU	.16	.28***	–.11	.23**	.23**	–.22**	.15	1.00
M	3.33	2.56	.57	2.06	.91	2.13	1.55	2.02
SD	.59	.25	.13	.24	.25	.18	.50	.64

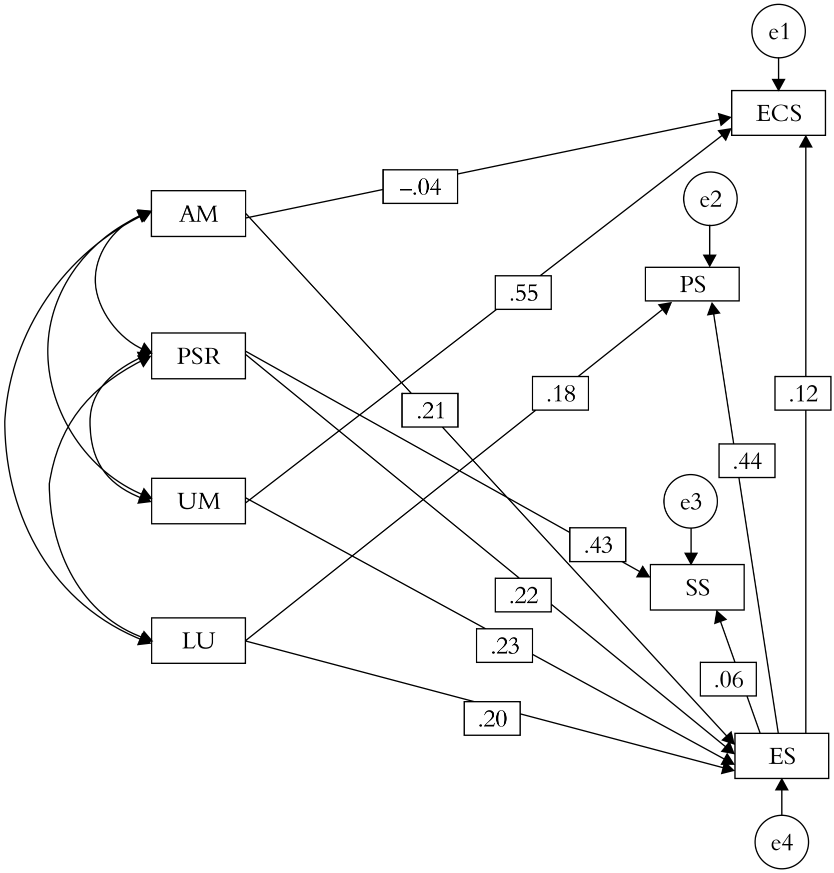
Notes: *p < .05, **p < .01, ***p < .001.
[a] ECS = Economic sustainability, PS = Psychological sustainability, SS = Social sustainability, ES = Ecological sustainability, AM = Adequacy of measures, PSR = Professional support received, UM = Understanding of measures, LU = Land use.

The four dimensions of technological capital were highly related with each other. Adequacy of measures and better professional support influenced each other. Adequacy of measures increased better understanding of measures and land use. More professional support increased understanding of measures, but decreased land use.

The bi-directional correlations failed to reveal the key sustainability parameter and antecedent-consequence relationships between dimensions of technological capital and sustainable livelihood. The multiple linear regression analysis was carried out using structural equation modelling to overcome the shortcomings.

The proposed model with standardized path coefficients (Figure 4) demonstrated the key sustainability dimension and impacts of the dimensions of technological capital on sustainable livelihood.

Figure 4
The Proposed Model with Standardized Path Coefficients



Notes: AM = Adequacy of measures, PSR = Professional support received, UM = Understanding of measures, LU = Land use, ECS = economic sustainability, PS = Psychological sustainability, SS = Social sustainability, ES = Ecological sustainability.

The results supported eight corollary hypotheses and refuted three (Table 4). The findings confirmed the conceptual and operational relationships between dimensions of technological capital and sustainable livelihood (Hair et al. 1998). Better understanding of utility of measures in a watershed increased economic

Table 4
Path Coefficients of the Proposed Model

Variable[a]	*Un-standardized Regression Weights*	*Standard Error*	*Hypothesis*
ES<—AM	0.19*	0.08	Accepted
ES<—UM	0.11**	0.04	Accepted
ES<—LU	0.07*	0.03	Accepted
ES<—PSR	0.30**	0.11	Accepted
SS<—PSR	0.33***	0.06	Accepted
ECS<—UM	0.64***	0.09	Accepted
ECS<—AM	–0.10	0.19	Refuted
SS<—ES	0.04	0.05	Refuted
ECS<—ES	0.29	0.20	Refuted
PS<—LU	0.07*	0.03	Accepted
PS<—ES	0.46	0.08	Accepted

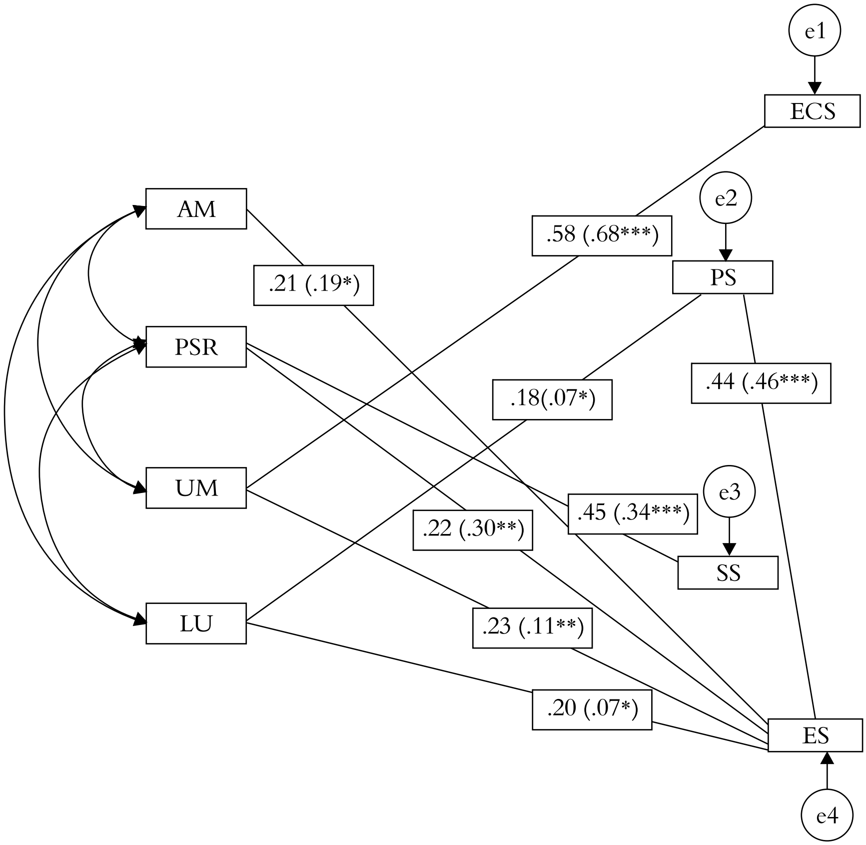
Notes: *p < .05, **p < .01, ***p < .001.
[a] ES = Ecological sustainability, AM = Adequacy of measures, UM = Understanding of measures, LU = Land use, PSR = Professional support received, SS = Social sustainability, ECS = Economic sustainability, PS = Psychological sustainability.

well-being of users. Better and increased land use improved the psychological happiness of beneficiaries. Ecological sustainability increased subjective well-being of beneficiaries. Professional support received for various watershed activities promoted social equity among users. Adequacy of measures, understanding of measures, better professional support received and more land use increased eco-friendly natural resource utilisation practices.

The testing of the proposed model could not present optimum value and significance of relationships between variables due to presence of non-significant paths. Therefore, improved model was estimated deleting non-significant paths. The improved path coefficients and significance level of parsimonious model were presented (Figure 5).

The hypothesized and parsimonious models were compared on fit measures (Table 5). Relative chi-square (χ^2/df) was taken because of the sensitiveness of chi-square to sample size. The relative chi-squares (χ^2/df) of the models were below the acceptable limit 2.5 (Kline 1998) suggesting the acceptability of both the models. Goodness of fit index (GFI) analogous to R^2 in multiple regressions, comparative fit index (CFI) indicates the overall fit of the model relative to the null model, and normed fit index (NFI) adjusts for the complexity of the model. GFI, CFI and NFI values of both the models were acceptable being above the limit of 0.9. Root mean square error of approximation (RMSEA) indicating the approximation of the observed to true model of the two models were below acceptable limit of 0.08. The fit measures of parsimonious model had no appreciable improvement over proposed model. However, the parsimonious

Figure 5
The Improved Model with Path Coefficients



Notes: Unstandardized beta indicated with significance is within parenthesis *$p < .05$, **$p < .01$, ***$p < .001$.
AM = Adequacy of measures, PSR = Professional support received, UM = Understanding of measures, LU = Land use, ECS = Economic sustainability, PS = Psychological sustainability, SS = Social sustainability, ES = Ecological sustainability.

Table 5
Fit Measures of Two Models

Model	χ^2	*df*	χ^2/df	*GFI*	*CFI*	*NFI*	*RMSEA*	*PGFI*	*PCFI*	*PNFI*
Proposed	13.06	12	1.09	.98	.99	.94	.03	.33	.43	.40
Parsimonious/ Improved	15.79	15	1.05	.97	.99	.93	.02	.41	.53	.50

measures (PGFI, PCFI, PNFI) being less sensitive to sample size, had shown some improvement in case of improved model. The improved model had also greater path coefficient values than the proposed model.

Discussions

The study covering 130 watersheds examines the impact of technological capital on livelihood of beneficiaries. Results suggest the appropriateness of the measures taken for the study. Understanding of utility of measures increases economy of households due to higher involvement of beneficiaries in livelihood activities. Increased and diversified land use practices of horticulture and agro-forestry enhance psychological happiness of users because of assurance of a better future. Better professional support promotes social equity among beneficiaries because of increasing belief in livelihood interdependence. Adequacy of measures creates new opportunities and thereby, deters livelihood-induced environmental degradation. Users with better understanding of measures nurture natural resources for continually deriving benefits. Land use practices according to land suitability foster better ecological balance due to increased productivity of land. Professional support provides technical know-how for improving ecological upkeep of the watershed. Understanding of measures, land use and professional support are critical technological parameters for influencing more than one sustainability dimension concerning household or community along with sustainable natural resource utilisation practices. Ecological sustainability of the watershed fosters psychological well-being of beneficiaries.

The finding is congruent with earlier observations that economically viable and socially acceptable technology improves economic well-being of users (Kerr et. al. 1996). Once the beneficiaries understand the importance and utility of agronomic and engineering measures in resource conservation and utilisation, they feel involved and take advantage of the measures in maximising economic returns. Users realize the importance of bio-physical interdependence and maintain treatments to deliver benefits now and also in future. In tribal- dominated high gradient areas beneficiaries possess less understanding of measures due to their apathy towards organized land use practices and thus yield poor economic returns.

Agreeing to earlier study, it is suggested that technology absorption influence livelihood in watersheds (McDonald and Brown 2000). Appropriate land use according to land suitability for livelihood on agriculture, horticulture, agro-forestry, forestry, floriculture, medicinal plant cultivation and so on increase psychological happiness of beneficiaries. It has been observed that people have confidence on land than non-land based livelihoods in non-tribal dominated comparably less gradient areas. The cash crops being less water intensive attracts attention of beneficiaries. Lands in slopes, not suitable for conventional agriculture, also call for diversification in land use.

The study supports earlier findings that adequate professional support is responsible for assimilation of technology into local livelihood system (Farrington and Lobo 1997; McDonald and Brown 2000). It has been observed that professional support influences equity among the community members. Professional support promotes land and non-land based livelihood activities of agriculture, animal husbandry, collection of non-timber forest products and other local skill-based occupations. Transfer of technology on agriculture and allied activities makes the users competent to pursue those livelihoods. Departmental support related to managing watershed council/ committee improves transparency and understanding between users.

The study approving earlier researches reveals that ecologically compatible technology influence livelihood in watersheds (Fujisaka 1989; Perez and Tschinkel 2003; Verbist et al. 2005). Adequacy of agronomic and engineering measures influences sustainable natural resource utilization practices. It provides a number of livelihood opportunities refraining people from destroying environment. Professional support helps in eco-friendly technology transfer. Beneficiaries with understanding of measures appreciate ecological relationships, and they are refrained from environmental exploitation. Effective land use practices promote conservation of natural resources.

Supporting earlier findings, the study also suggests ecological sustainability of the watershed to be the cornerstone of livelihood sustainability (Carney 2002). Natural resources being the sources of livelihood, qualitative and quantitative improvement of land use, water, forest, plants bring psychological happiness to beneficiaries. Ecological sustainability maintains bio-physical equilibrium in a watershed. It gives opportunities to households to adopt varied livelihood activities. People feel assured of deriving similar or better benefits in future as they are doing it now. The realization of livelihood interdependence rationalizes behaviour of users towards environment and others.

The lack of influence of adequacy of measures on economic sustainability can be attributed to more number of young WDM schemes in the sample. Ecological sustainability does not determine economic and social sustainability because it can not determine them without interventions of understanding of measures and professional support. The inverse relationship of professional bias with land use is due to motivation of beneficiaries towards higher quick yielding non-land based activities of animal husbandry, collective marketing of non-timber forest products and other indigenous skill-based occupations than long yielding land use practices.

Maintenance arrangement and professional bias not taken for analysis are critical in determining livelihood sustainability. Although, beneficiaries have reported to conduct maintenance of measures collectively, it will be disastrous if no one takes care of the treatments as it has happened in many watersheds after withdrawal (Kerr et al. 1996). Agronomic measures against the professional bias for engineering measures need to be given due importance for livelihood sustainability in watersheds. From the above discussions, it is concluded that higher the technological capital, better is the livelihood sustainability in a watershed.

The study is unique in assessing watershed technology from users' rather than bio-physical perspectives only. Bio-physically appropriate technology speaks of resource conservation but hardly reveals livelihood expectations. The parameters of economic viability, social acceptability and ecological compatibility of technology adoption and adaptation taken in earlier studies are mostly confined to appropriateness of technology. Whereas, the parameters of adequacy and understanding of measures, professional support, and land use taken in the study are more concerned about livelihood sustainability. All technology that sustain livelihood are appropriate but not the vice-versa. Parameter-like professional bias needs to be given due importance in assessing impact of technology. Psychological sustainability dimension of sustainable livelihood taken in the study is a novelty for rural community-based development programmes like WDM. Empirical study covering 130 watersheds of different funding and executing agencies indicate rationality of the findings. Both qualitative and quantitative assessments have been incorporated to lend complementary support to each other (Patton 1997). Exclusive visual tools have been developed for data collection suitable to socio-cultural context of beneficiaries.

Some of the policy implications emerging out of the study are: (*a*) attaining adequacy of agronomic and engineering measures at least to the extent of 75 per cent within first two years of WDM, (*b*) intensive professional support on land use practices, (*c*) introduction of incentive schemes for better land use practices, (*d*) organizing frequent exposure visits to comparable watersheds for better transfer of learning, (*e*) training of beneficiaries on utility of measures and maintenance needs (*f*) sensitizing people on importance of ecological sustainability of the watershed through awareness and training programmes with emphasis on human-environment relationship, and (*g*) creating detailed database of watersheds at block level and obtaining data in every three years even after withdrawal for establishing sustainability.

The study has some limitations that must be acknowledged. First, due to unavailability of longitudinal data the study has been based on one-time data to establish trend of sustainability rather than its absolute value. Second, 130 watersheds of Orissa (India) have been studied; therefore caution must be exercised in generalizing the findings. Further research can be carried out in finding types and optimum level of professional support requirement for fostering better land use.

CONCLUSION

WDMs need to be assessed along the parameters of technological capital, so that thrust areas can be prioritized for corrective measures. Professional support need to be provided looking into local needs and opportunities rather than a generalized package. Integrated planning of micro watersheds is essential to avoid overlapping, duplication and resource loss of competing schemes. The bio-physical condition of the watershed needs to be thoroughly analyzed for assimilation of technology into the local livelihood system. It is better to associate local people more in the problem identification, planning and design phases of the project for absorption of technology. The land use practices of medicinal plants, floriculture and agro-forestry are yet to be established as viable source of livelihood. Therefore, agencies need to be deployed to establish dependable market links for such products so that, these land use practices can be viable to beneficiaries of watersheds.

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