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Influencing factors of adopting solar irrigation technology and its impact on farmers' livelihood. A case study in Bangladesh

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Access to irrigation is considered critical for agricultural growth in Bangladesh. Solar-powered irrigation system (SPIS) has emerged as a promising technology for sustainable irrigation practice in the country. This study reports the factors that affect the adoption process of SPIS in the farming community. It also explores the impact of SPIS projects on the livelihood status of the farmers. In this regard, 140 farmers were directly interviewed from the Meherpur district of Bangladesh. Random sampling techniques were followed, and probit model analysis was conducted to identify the socio-economic factors that affect the adoption process. Capital and composite livelihood indices were prepared to examine the impact of SPIS projects on farmers' livelihood status. The result shows that education and extension services had a statistically positive effect on adoption. By contrast, access to credit, farm size, and off-farm income had a significantly negative impact on the adoption process. The result also shows that farmers using solar-powered irrigation technology had a better livelihood index in different indicators, i.e., human, social, natural, and technical capital, than diesel-powered irrigation system users.

1. Introduction

Irrigation is recognized as a measure that can enhance multiple cropping practices and improve yield (FAO, 2011). The agricultural success stories of Bangladesh have also been credited to the irrigation facilities developed countrywide (United Nations, 2015). There are nearly 1.61 million irrigation pumps currently active in the country (MOA, 2021). Among them, 83% of the pumps are operated by diesel engines. In order to keep them running, a supply chain of diesel fuel has been developed in the rural areas. However, the problem is that the fuel is heavily subsidised (Ahmed, 2010) by the Government of Bangladesh to keep the food production cost low. From this perspective, replacing diesel-powered pumps with solar-powered electric pumps seems more justified. Moreover, diesel-powered irrigation pumps emit large quantities of greenhouse gas. A recent study by Rana et al. (2020) showed that replacing half of the diesel pumps with solar pumps can reduce Bangladesh's carbon footprint by one million tons per year.

Bangladesh started deploying full-fledged solar-powered irrigation system (SPIS) projects in 2009. It is estimated that replacing all diesel water pumps with SPIS will generate 10,000 megawatts of solar energy (Halder et al., 2015). Bangladesh has since laid out a lavish plan to implement solar-powered irrigation systems which is expected to play an important role in Bangladesh's present and future energy mix. Solar-powered projects are mainly overseen by Infrastructure Development Company Limited (IDCOL), a government-owned company. IDCOL works with different non-government organizations and local private enterprises to implement SPIS. In addition, they also provide training on modern crop production practices regularly. Training is provided to those farmers who are eager to adopt new technology in irrigation (IDCOL, 2015). In recent years, the adoption of SPIS in Bangladesh has been growing but slowly, with a total installed capacity of 48.13 MW (SREDA, 2021).

The adoption of new agricultural technology like SPIS is a complex endeavour. The adoption process is thought to be mainly profitability related issues (Davies, 1979). The World Bank (2015) reported that SPIS has indeed reduced the irrigation costs in Bangladesh. Similar results have also been reported by Zakaullah et al. (2021), Kelley et al. (2010), and Khan et al. (2013), who found SPIS to be profitable for at least 5 years. From this perspective, the adoption of SPIS should have been easy. However, the slow growth of SPIS in Bangladesh has raised questions about what factors are affecting the process. It has long been argued that technology adoption decisions are based on heterogeneous factors such as human capital, farm size, information about technology, cost, risk, benefit, etc. Other factors like farm size (Akudugu et al., 2012), gender (Atibioke et al., 2012), higher education (Uddin et al., 2014), longer experience (Ainembabazi and Mugisha, 2014), age of farmers (Mendola, 2007), larger incomer earner (Mottaleb et al., 2016), neighbor's adoption, and land ownership (Hailu et al., 2014) have also been discussed in the literature.

Communication channel (Rogers, 1995), types of innovation (Goodhue and Thompson, 1995), nature of the social system, performance impact, and subject norms (Taylor and Tood, 1995) are also thought to be amongst the influencing factors. A study on the adoption of solar-powered irrigation systems found that different scales of farming (Smallholder, commercial, and subsistence) and several irrigation practices (fuel-based, grill-connected, and rained) need to be evaluated before examining the adaptation options (SNVNDO, 2014).

Despite the financial benefits, SPIS also has important impacts on people's living conditions. A study by the International Water Management Institute (2015) commented that the benefits of solar irrigation systems include increased social welfare (emissions reduction, poverty alleviation), improved livelihoods (increased incomes, productivity, and food security), and reduced spending on subsidized fuel and centralized infrastructure. Although scientific literature on the financial preferences (Sattar and Rahman, 2004; Hoque et al., 2016; Hossain et al., 2015; Khan and Pathik, 2014; Agrawal and Jain, 2010; Odeh et al., 2010 and Shah et al., 2014) of solar irrigation projects are abundantly found, very few of them, however, talk about the impact of SPIS on the farmers' livelihood status. Livelihood indicators can be categorized as social, technical, human, physical, natural, environmental, financial, or even economic (Green and Haines, 2002; Kamruzzaman and Takeya, 2008; Lowe and Schilderman, 2001). This manuscript reports the results of a study carried out to shed some light on this area of concern.

2. Materials and Methods

2.1. Selection of sample and sample area

The study was conducted in cooperation with IDCOL at the Meherpur district of Bangladesh. Paddy growing farmers were interviewed from 12 July to 28 July 2019 with the help of the Resource Development Foundation (RDF), a local non-government organization (NGO). In this research, two types of farmers were considered, the target group and the control group. The target group was those who were involved in SPIS projects. Both category farmers were based on the community, and their livelihood depended on agriculture production. A well-designed questionnaire was used for collecting data about farm-level characteristics and the livelihood of farmers. Before conducting the study, pretesting and focus group discussions were conducted in the desired study area. A total of 140 farmers were interviewed of which, 80 farmers were SPIS users, and the remaining 60 were

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Table 1. List of abbreviation

FAO	Food and Agriculture organizations
MOA	Ministry of Agriculture
IDCOL	Infrastructure Development Company limited
SNVNDO	SNV Netherlands Development Organization
USAID	United States Agency for International Development
IWMI	International Water Management Institute
NGOs	Non-Government Organizations
IPM	Integrated Pest Management
HYV	High Yield variety

diesel pump users. Finally, 130 sample data (72 SPIS and 58 diesel pump users) were considered for analysis. The rest of the sample data was discarded due to incomplete information.

2.2. Analytical Tool

A binary regression model was used to discover the parameters influencing the adoption of solar-powered irrigation systems. Commonly, probit and logit models are used extensively in econometrics to formulate the functional relationship between the adoption probability and factors. Many studies were conducted using binary models to identify the determinants of single technology adoption (Mariano et al., 2012, Chuchird et al., 2017 and Karidjo et al., 2018). For this specific study, a probit model was used to identify the factors influencing the adoption of solar irrigation systems. The dependent variable has two categories in the probit model and is represented statistically by a probability distribution (Liao, 1994). The cumulative normal probability distribution is the foundation of probit analysis. The binary dependent variable, y, has 'zero' and one values (Aldrich and Nelson, 1984). For the analysis purpose, a farmer is considered an adopter who adopts SPIS and assigns a score of one, and 0 who used a diesel/electric powered irrigation system.

$$Y_i^* = Y_{ip} - Y_{iq} > 0 = \beta + \beta_i X_i + U_i$$

$$Where\ U_i \sim N\ (0,1), i = 1 \dots n$$

$$Y = 1\ if\ Y^* > 0, otherwise$$

Here, Y_i* represents the adoption probability of SPIS, where Yip and Yiq represent SPIS adopters and non-adopters, respectively. β_i , represent the coefficient of the variable, where X_i represents the independent variable that influences the adaptation of the solar-powered irrigation system.

The empirical model for this analysis is below,

$$Y = \beta_0 + \beta_1 X_A + \beta_2 X_E + \beta_3 X_{FS} + \beta_4 X_{ES} + \beta_5 X_{AC} + \beta_6 X_I$$

Here Y stands for the probability of adoption (1= SPIS adopters, 0 otherwise), X_A = age of the respondent (years), X_E = Year of education (school year), X_{FS} = Total amount of cultivable land (hectare), X_{ES} = frequency of contact with extension personal, X_{AC} = Access to credit (1 = availability of credit, 0 otherwise), X_I = Income of the respondent (tk.).

2.3 Livelihood Index Analysis

The accuracy of the measurement of livelihood status depends on selecting an appropriate indicator and their issues. The present study attempted to identify six indicators potentially affected by the solar-powered irrigation project. These indicators were social capital, human capital, physical capital, natural capital, technical capital, and financial capital. Each type of capital had various sub-indicators yielding in different categories. Extensive pretesting and focused group discussions were conducted in the study area to select the capital index component. The details about the valuation of different livelihood indicators are presented in appendix A. The weighted capital index and composite livelihood index were prepared based on the principle of the multi-criteria analysis method (Nijkamp, 1990; Hyde et al., 2004). The concept of this method was studied from Sullivan et al. (2010). The formula for capital index and composite index is discussed below:

The capital index of each farmer was computed using the following formula.

$$CI = \frac{\sum W_i}{MS} \times 100$$

CI= weighted capital Index (Social capital, Human capital, Physical capital, Natural capital, Technical capital, and Financial capital).

W_i = Weighted of the ith individual issue of each capital obtained

MS = Number of individual items/issues of each capital multiplied by the maximum score assigned for individual issue.

The composite livelihood index of each respondent consisting of six capitals was expressed as bellows.

$$CLI_i = \frac{W_1HCI_i + W_2SCI_i + W_3NCI_i + W_4PCI_i + W_5TCI_i + W_6FCI_i}{W_1 + W_2 + W_3 + W_4 + W_5 + W_6}$$

CLI_i = Composite livelihood of ith respondents
HCI_i , SCI_i , NCI_i , PCI_i , TCI_i , FCI_i represent the weighted human, social, natural, physical, technical, and financial capital

$W_1 - W_6$ = Mean weight of respective capital derived by taking the average weights of all individual items/issues.

2.4. Weighting scheme used for Composite capital analysis

Several studies (Murphy and John, 1996; Noble et al., 2010 and Sullivan et al., 2010) have reported using the weighting function to develop capital index in livelihood studies. Accordingly, each of the six major components was assigned with equal values. Similarly, the sub-components were also given equal weight within the component assuming that each component is coequal in contribution towards livelihood status.

3. Results

3.1. Factors affecting farmer decisions to adopt solar irrigation system

The result of probit analysis on finding factors responsible for adopting a solar irrigation system is presented in Table 2. It shows the omnibus test result mainly representing the likelihood ratio chi-square test. The objective of this testing is whether the model containing our set of predictors represents a significant improvement and is fed over an unconditional model with no predictors. Here, the omnibus test result indicates that our model containing the predictors represents a significant improvement and fit over the unconditional model. The R square result explains that the independent variable can explain nearly fifty percent of the change in the dependent variable. Table 2 shows that the coefficient of education was statistically significant and yielded a positive sign indicating that it leads to human capital development. This analysis supports the hypothesis that human capital has a positive role in evaluating and acquiring new technology. The coefficient of extension service contact had a significantly positive impact on the adoption of a solar-powered irrigation system. This finding acknowledges that farmers are likely to be influenced by the extension service's information since these sources are considered credible.

The co-efficient of farm size was found to significantly impact the decision on adopting a solar-powered irrigation system., however yielding negative signs. Here, the farm size was considered a proxy to the farmers' wealth, and the findings suggest that large farmers do not necessarily adopt a solar-powered irrigation system. Another variable, access to credit and off-farm income were also found to have a significant negative impact on the decision-making process. Farmers who had seemingly extra farm income tended towards investing in non-farm sources, which provided them larger returns than agriculture.

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Table 2. Result of Probit Model Regression

Variable	Estimate (S.E)	Margin Estimate
Constant	.988	
Experience	0.010 (0.018)	0.0017(0.003)
Education	.236***(0.078)	0.043***(0.013)
Farm Size	-0.032*(0.055)	-0.006*(0.009)
Family Size	.058 (0.109)	0.015(0.019)
Extension Service	.944** (0.368)	0.172**(0.06)
Access to Credit	-.676* (0.377)	-0.123*(0.065)
Off-Farm Income('000)	-0.0043*** (0.00009)	-0.0008***(0.00001)
Log likelihood Ratio (Omnibus test)	86.735	
R square	0.49	

(*, ** & *** indicate 10%, 5% and 1% level of significance respectively)

3.2. Livelihood capital indicators

The results of human capital indicators are shown in Table 3. The human capital index consists of four components. In the case of the knowledge about the profession, the target group's mean value was higher than the control group. A similar situation was found for health condition indicators. Better health conditions can be attributed to the government's better financial condition and awareness other variables represent that the maximum member of the target group had passed the primary education (Table 3), and some of the members have passed more than primary education. The majority of the control group members had passed primary education or below. Very few people attended secondary education. Better results of the target group on training received can be attributed to the constant training provided by the IDCOL to the solar-powered irrigation user.

Social capital was studied by analysing seven indicators. The mean value of the relationship with focused group personnel of agriculture and the relationship with other farmers was higher for target group people. In the same way, the mean value of social relations for the target group was also much higher than the control group. However, the mean value of a member of the co-operative organization, relationship with financial organizations was higher for the control group. Normally, control group people were involved in off-farm activities in the study area. Thus, they need to contact the financial organization more than target group people. This result is supported by Table 3, which proved that off-farm activities had a negative impact on adoption. Additionally, the control group had more local government participants than the target group participants. Findings also showed that the control group had a better relationship with the point of sale than the target group farmers, although their overall relationship with the point of sale was poor. It was also found that farmers in the study area usually sold their products to random buyers.

In natural capital, the mean value for compost pit, cow dung, and pit for the household was higher for the target group (0.14, 0.6, 0.34, and 2.31) than the control group (0.1, 0.54, 0.32, and 1.52, respectively). The result showed that farmers who used solar-powered irrigation systems are more aware of preserving and using organic material in the field. The study also revealed that the target group had better irrigation facilities in terms of irrigation cost, water availability, and labour requirement.

On the other hand, the control group had better housing facilities and agriculture implementation for physical capital. Most of the control group farmers had shallow pump machines. The income source of most of the control group farmers is related to off-farm activities. Thus, control group farmers had a better score in agriculture equipment and housing facility. However, solar-powered irrigation projects can be seen in sanitation and housing furniture, where little investment is required. The findings showed that the target group had a slightly better position in terms of sanitation facilities and furniture in the house.

In addition, most control group farmers had centrifugal pumps for shallow depth groundwater extraction. Moreover, sanitation facility and household furniture indices were higher for target group farmers. The study results also show (Table 3) that the target group people were better off in terms of technical capital and are conscious about soil health. Similarly, the target group had better production-related knowledge and information source than the control group. Farmers in the study area collected information mostly from retailers or other farmers about different production-related information. SPIS project beneficiaries, have easy access to the government expert about insecticide use and production methods. Thus, the target group had a better position in these two parameters (1.91 and 1.92, respectively).

In financial capital, the mean value of agriculture source income, livestock, and poultry were higher (2.37, 1.66, 1.38, 0.40, 0.42) for the target group, although quite similar to the control group (2.26, 1.62, 1.46, 0.3, and 0.54 respectively). The slightly higher income from agriculture sources can be attributed to the reduction in production cost and the development of farming methods due to constant training. In contrast, the mean value of off-farm income was higher for the control group, and this was expected as most of the control group farmers were involved in the off-farm activity. The result also showed that target group farmers were more interested in savings than the control group. Conversely,, the control group farmers had more credit facilities than the target group.

The weighted mean value of different capitals is presented in Table 4. The result revealed that solar-powered irrigation users had a better score in human capital, natural capital, technical capital, and financial capital than the control group . But, the score for physical capital was higher for control group farmers. The composite capital calculated by taking the weighted mean value of all capital was higher for target group people. The result indicated that farmers had developed their livelihood by adopting the solar-powered irrigation system in the study area, which is reflected in different livelihood capital.

Additionally, a mean independent t-test was conducted to test the significance of the difference between the weighted capital indicators. The result revealed that the target group's human, natural, and technical capital indices differ significantly ($p=0.01$) (Table 4). These three indicators reflect the impact of solar-powered irrigation systems on the development of farmers. Moreover, the significant difference in the composite capital score leads to the conclusion that there was a significant difference between these two groups of people.

4. Discussion

This study revealed the socio-economic factors affecting the farmers' adoption of solar-powered irrigation systems (SPIS). Findings showed that education, farm size, extension service contact, access to credit, and off-farm income significantly impacted adoption decisions. Particularly, education and extension service contact had a positive impact where farm size, access to credit, and off-farm income had negatively impacted the adoption decisions. The positive sign signifies the role of education in adopting the new technology in agriculture. Bacha et al. (2011), Chirwa (2005), and Huang & Karimanzira (2018) also reported similar findings from their respective studies.

According to the results of this study, the extension service contact has emerged as an important tool that determines the farmers' mind, although Rahman and Norton (2019) reported otherwise. Besides, , farm size had negatively influenced the farmers' adoption decision. This finding is consistent with Diiro and Sam (2015), Huang & Karimanzira (2018), and Demeke & Croppenstedt (1996) but is in contrast with Rahman, & Norton (2019), Chirwa (2005), and Isham (2002). Apparently, large farmers are still skeptical about investing in a new technology that is being operated on a small-scale basis only in Bangladesh. They do not feel encouraged to invest large amounts of money unless significant government support is provided. They would rather invest in the diesel-powered irrigation system they have been used to.

Moreover, finding on "off-farm income" are contrary to the findings of Chirwa (2005) but consistent with the finding of Alabi et al. (2014) and Makokha et al. (2001). These two results revealed financial insecuri-

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Table 3. Mean value of livelihood capital indicator.

Component	Solar Powered Irrigation System user	Diesel Powered Irrigation System User
Human Capital		
Knowledge about profession	2.042	1.94
Health condition	2.242	2.04
Educational status	1.242	1.08
Training Received	1.75	0.9
Social Capital		
Relationship with focused group personal of agriculture	1.34	1.22
Co-operation with farmer	2.51	2.3
Membership of co-operative organization	0.56	0.6
Social relation	2.7	2.38
Relationship with financial organization	1.5	1.86
Participate in local government	1.2	1.18
Relation with point of sale	0.78	0.84
Natural Capital		
Ownership of compost pit	0.14	0.1
Ownership of cow dung pit	0.6	0.54
Ownership of pit for household waste	0.34	0.32
Irrigation	2.31	1.52
Physical Capital		
Housing Facility	1.69	1.98
Sanitation Facility	1.87	1.78
Ownership of agricultural implement	1.94	2.14
Ownership of household furniture	2.19	2.06
Technical capital		
Improving soil health	0.96	0.86
Technical information source	1.56	1.24
Knowledge about insect and pest	1.91	1.72
Knowledge about production technology	1.92	1.68

Continue Table 3. Mean value of livelihood capital indicator.

Financial capital		
Agricultural income	2.37	2.26
Fisheries/livestock	1.66	1.62
Non-agricultural income	1.38	1.46
Savings	0.4	0.3
Credit availability	0.42	0.54

Table 4. Weighted value of different livelihood capital.

Component	Solar Powered Irrigation System User	Diesel Powered Irrigation System User
Human Capital	15.27 ***(4.064)	12.49
Social Capital	7.43 (NS) (1.821)	6.86
Natural Capital	14.07 ***(4.589)	10.56
Physical Capital	16.31 (NS) (-.463)	16.68
Technical Capital	13.29 ***(2.717)	11.74
Financial Capital	10.47 (NS) (1.735)	9.50
Composite Capital	13.52 ***(3.873)	12.01

(*, ** & *** indicate 10%, 5% and 1% level of significance respectively; NS represent "non-significant")

ty present in the agricultural sector. Farmers who had extra sources of income normally invest in the non-farm agriculture source as these sources are related to a higher return on investment.

In order to achieve the SGD goals, the government of Bangladesh is dedicated towards investing in renewable energy. To achieve this, target-based policies to promote SPIS adoption are needed. Since education has a positive role, the young farmers, in particular, should be offered vocational training. Extension services also need to be fortified as it has the biggest influence on the farming community. This study indicates that SPIS projects have failed to attract large farmers. Proper information and targeted extension contact may help encourage large farmers. In such cases, crop insurance policy can also be introduced to safeguard their income. The negative influence of credit access and off-farm income reveals that agriculture is still a subsistence sector in Bangladesh.

The second part of the study represents the impact of solar-powered irrigation systems on the farmers' livelihood. In order to study the effect, the livelihood capital indicators between the solar-powered irrigation system and the diesel-powered irrigation system were compared. Six capital indicators were selected. Findings revealed that all the components of human capital for solar-powered users had the upper hand over diesel-powered users. Human capital development can relate to the continuous contact of NGOs and regular government agency training. SPIS users also had better social, natural, technical, and financial capital. However, diesel-powered irrigation users had better housing and agricultural equipment than SPIS users. These findings indicate that SPIS farmers have developed their human, social, natural, financial, and technical capital. These developments can be related to the gain from SPIS projects in financial, training, and other facilities.

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5. Conclusion

This study reports the results of a study to explore the factors that affect the adoption of solar-powered irrigation systems (SPIS). It also reports the effect of SPIS projects on the livelihood standard of the farmers in the studied area. A total of 140 farmers were interviewed in this regard. We analysed the intervention of this project on the different capital components. This study concludes that farm-level socio-economic character influences farmers' adoption of solar irrigation systems. Among them, education and "extension services contact" had a significantly positive role in adopting SPIS. Besides, access to credit, farm size, and off-farm income negatively impacted the adoption process.

This study also concluded that SPIS projects positively impacted on the farmers' livelihood status, particularly on the development of human, social, natural and technical capital. The significant difference in the composite capital score led to the conclusion that SPIS had a substantial impact on the development of the livelihood status of farmers. This study recommends that further inquiries be made to understand the dynamics of adoption amongst the large farmers.

Conflict of Interest

The Authors declare no conflict of interest.

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Appendix A. Valuation of livelihood Index

Human Capital	
Parameter	**Score**
Knowledge About Main Profession	1.1-4 answers correctly; 2. 5-7 answers correctly; 3. 8-10 answers correctly;
Health Condition	0. Seriously sick; 1. Poor health condition; 2. Moderate health condition; 3. Good health condition.
Education Status	0. No education; 1. can sign or maximum 5 years; 2. complete education between 6-10 year; 3. complete education more than 10 years.
Degree of training received	0. No training; 1. minimum 1-day training; 2. minimum two training; 3. more than two training.
Social capital	
Relationship with focused group personal of agricultural	0. No visited either agriculture office or livestock office or any agricultural research centre or bank; 1. Visited one organization; 2. Visited two organizations; 3. Visited three or more than organization.
Extent of Co-operation with Farmers	0. No co-operation; 1. Poor co-operation; 2. Moderate co-operation; 3. Always co-operation.
Membership of co-operative organization	0. No membership; 1. Member of one organization; 2. Member of two organizations; 3. Member of three or more organizations.
Social relations	0. No visit; 1. Once in a year; 2. Visit in every half year; 3. Visit in every 4th month; 4. Visit in every month.
Relationship with point of sale	0. No co-operation; 1. Poor co-operation; 2. Moderate co-operation; 3. Always co-operation.
Relationship with financial institutions	0. No visit; 1. Once in a year; 2. Visit in every half year; 3. Visit in every 4th month; 4. Visit in every month.
Participation in Local government	0. No participation; 1. Minimum participation; 2. Average participation; 3. Frequent participation; 4. Always participation.

Continue Appendix A. Valuation of livelihood Index

Human Capital	
Parameter	**Score**
Natural Capital	
Ownership of Composite Pit	0. No ownership; 1. ownership
Ownership for Pit for Cow Dung	0. No ownership; 1. ownership
Ownership of Pit for Household Waste	0. No ownership; 1. ownership
Irrigation	1. Low satisfied; 2. Moderate satisfied; 3. High Satisfied.
Physical Capital	
Housing facility	0.No housing; 1. owned either bamboo made wall + straw thatched roof + muddy wall or muddy floor + corrugated sheet or muddy wall+ corrugated sheet roof + muddy floor type house; 2. either corrugated sheet or muddy wall + corrugated sheet roof + muddy floor house; 3. either owned brick wall + corrugated sheet or concreate roof +concreate floor house.
Sanitation facility	0.No housing; 1. either ring slab or open pit + bamboo made wall or plastic bag surroundings + straw thatched roof; 2. either ring slab + corrugated sheet wall + corrugated sheet roof; 3. concreate sanitation facility.
Ownership of Household Furniture	0.No ownership; 1. total value of furniture didn't exceed 15000tk; 2. total value of furniture found between 15000 to 40000 tk; 3. total value of furniture more than 40000 tk
Ownership of agricultural implement	0. No ownership; 1. at least 1 agricultural implement owned; 2. at least two agricultural implement owned; 3. more than two agricultural implement owned.
Ownership of livestock and poultry	0.No ownership; 1. total value of livestock and poultry didn't exceed 10000tk; 2. total value of livestock and poultry found between 10000 to 50000 tk; 3. total value of livestock and poultry more than 50000 tk
Technical Capital	
Improving of soil health	0. No measure either cow dung or crop residual, mulching crop; 1. Minimum (only use cow dung); 2. Cow dung and residual; 3. Only mulching.
Receiving of technical information	0. No use information; 1. Use of only source; 2. Use of two sources; 3. Use of three sources; 4. Use of more than three sources.
Knowledge of insect and pest	0. No knowledge; 1. Minimum knowledge (have knowledge common insect and pest); 2. Moderate knowledge (have knowledge about all insect and pest of rice); 3. Sufficient knowledge (have knowledge about pest and insect control); 4. Complete knowledge. (knowledge about everything including IPM).
Knowledge about production technology	0.No knowledge; 1. Local production technology; 2. Have knowledge about local production technology and HYB/production technique; 3. Have knowledge about local production technology, HYB production technique; 4. Complete knowledge about production technology and use modern technology
Return from agricultural produce.	0. No return; 1. Up to 25000 tk; 2. Between 25000 to 50000 tk; 3. more than 50000 tk

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Continue Appendix A. Valuation of livelihood Index

Human Capital	
Parameter	**Score**
Return from livestock-poultry and their products.	0. No return; 1. Up to 10000 tk; 2. Between 10000 to 25000 tk; 3. more than 25000 tk
Return from non-agricultural sector	0. No return; 1. Up to 50000 tk; 2. Between 50000 to 150000 tk; 3. more than 150000 tk
Savings	0. No Savings; 1. Up to 1000tk per month; 2. Between 1000 to 5000 tk; 3. more than 5000 tk
Credit receive	0.No availability of credit for agriculture; 1. Available credit facility for agriculture

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