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DOES MICRO HYDROPOWER IMPROVE PRODUCTIVITY OF MAIZE CROP? A CASE OF RURAL KHYBER PAKHTUNKHWA

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ABSTRACT

Micro hydropower (MHP) schemes play an important role in socio-economic development of an area. This study attempts to identify the effects of MHP schemes on productivity of maize crop in three selected tehsils namely Alpuri, Besham and Puran of district Shangla, Khyber Pakhtunkhwa, Pakistan. A total of 220 households were randomly selected from the selected tehsils. Primary data were collected through a questionnaire-based survey. Binary logit model was used to find out the effects of MHP scheme on productivity of maize crop in the research area. The results of the estimated model confirm that MHP scheme has a positively significant effect on productivity of maize crop and thereby, income of people in the study area, as shown by the p-value less than 0.05. The overall model was highly significant which confirms that MHP positively affects productivity of maize crop and income of the farmers. The study concludes that electricity produced from MHP schemes has an important role in socio-economic and sustainable agricultural development in the research area in specific and rural areas in general.

Keywords: agricultural productivity, electricity, micro hydropower, post-harvest activities

INTRODUCTION

Energy plays a key role in the economic development of a country and is a pre-requisite for attaining an inclusive economic growth. Apart from the economic growth of the economy, access to energy has a large impact on social, human and environmental aspects of development. Poverty alleviation, reduction in health issues, gender balancing, and enhanced agricultural productivity are all related to energy consumption (Jan *et al.,* 2021).

Besides, energy plays an important role in increased food production in many countries. Food production activities entail a set of agricultural activates such as irrigation, land preparation, fertilization, food processing, and conservation (Babutande *et al.,* 2019). Agricultural practices in developing countries are mostly based on fossil fuel consumption which contributes significantly to global warming and environmental degradation (Jan and Lohano, 2021). Farming based on clean energy is the best solution to mitigate global warming and environmental degradation (Clement *et al*., 2018). Global attempts to reduce the reliance on fossil fuels require consideration of clean energy pattern in agriculture practices (Kennedy, 2000). Clean energy is used in various agro-based industries like rice mills, corn mills, tea factories, and chilling milk, etc. (World Bank, 2017).

Pakistan's population is increasing at a faster rate (Jan *et al.,* 2017). To meet the increasing demand of food for the burgeoning population in Pakistan, farmers have to expand the use of energy intensive farming practices. However, the energy intensive agricultural practices have consequences for both energy security and environmental sustainability (Imran and Ozcatalbas, 2020). Hence, the need is that farmers rely mostly on clean and sustainable energy sources such as electricity. Agriculture sector is the major consumer of electricity in Pakistan. According to official estimates, the agriculture sector of Pakistan consumes 12.2 percent of the total electricity (GoP, 2020). In rural areas in Pakistan, where people have problems in accessing the grid electricity, government and non-governmental organizations (NGOs) have initiated MHP schemes for electricity provision.

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Electricity consumption indicates the development of all sectors of an economy including agriculture sector. The governments of Pakistan and Khyber Pakhtunkhwa are keen to provide electricity to the unserved area through different means such as main electricity grid or MHP schemes. The Pakhtunkhwa Energy Development Organisation (PEDO) with the technical assistance of Sharad Rural Support Programme (SRSP) is working on community based MHP schemes in district Shangla with the aim to provide reliable and cost effective electricity to rural communities. PEDO had installed several MHP schemes in district Shangla. The encouraging point in using MHP was that the project was providing electricity at a fix rate to every household irrespective of the size and use. Hence, the electricity from MHP schemes was cheaper as compared to electricity from the main grid for which bills were charged as per actual amount of electricity used.

MHP based electrification has a significant impact on livelihoods of rural populations. Initiating livelihood activities such as agriculture, dairy farming, poultry farming, and businesses boosts the economic activities of rural people (Korkeakoski, 2010). In case of inability to have access to main electricity grid, MHP plays a key role in fulfilling households' energy demands. Thus, access to MHP electricity enables consumers to operate their farm practices and businesses which in turn brings them more income and benefits (Siraj and Khan, 2019).

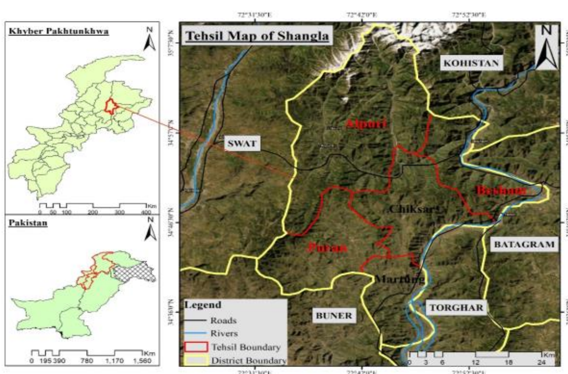

Figure 1. Map of Pakistan showing the research location

MHP schemes are the main sources of socio-economic gains in rural areas (de Faria *et al*., 2017). The social gains include improved education, health, and access to clean water. In Nepal, traditional kerosene oil lamps were totally abandoned and firewood consumption was reduced because of electrification due to MHP. Besides, the electricity from MHP was used to operate modern agro-processing mills which helped in reduced drudgery for women (Gurung *et al.,* 2011). Economic gains include increased productivity in home enterprises and intensification of agricultural activities. In countries like Vietnam, electric water pumps have replaced manual irrigation which has led to increase in agricultural income (Khandker *et al.,* 2013).

Saqib *et al.* (2013) found that micro hydro-power schemes in Pakistan are important for on-farm and off-farm employment such as cottage industry, rice mills, saw mills, storage systems, and poultry farming. These small industries and businesses require energy which is provided by MHP schemes in the respective areas.

This paper attempts to investigate the role of MHP schemes on agricultural productivity of maize crop in district Shangla, Khyber Pakhtunkhwa Province of Pakistan. Previous literature mostly investigates the role of MHP on fulfilling energy needs of the households. The contribution of this paper is novel in the sense that it investigates the relationship between electricity from MHP schemes and agricultural productivity in the research area.

MATERIALS AND METHODS

The research study was carried out in district Shangla of Khyber Pakhtunkhwa Province in Pakistan from September-December, 2019 see Figure 1. District Shangla is the sub-division of Malakand region of Khyber Pakhtunkhwa, with hilly terrain. Because of the terrain and annual precipitation rate along with the downstream flow of water, there is a huge potential for MHP systems in district Shangla, which needs to be exploited to fulfil energy needs of the local people. Due to weather of the area, its hilly terrain, and unavailability of water, only maize is the main crop grown in summer. Besides, some winter vegetables are grown but the production is very minimal. Therefore, maize as the sole main crop of the area, was selected for this study.

Three tehsils namely Alpuri, Besham and Puran in district Shangla were selected for the study. The total number of households in the area were 49864 (Alpuri=32776, Besham=7913, Puran =9175). A total of 145 households from tehsil Alpuri, 35 households from Besham, and 41 households from Puran were selected through proportional allocation sampling technique. Thus, a total of 221 households were randomly selected from the total households. During the final survey, one respondent was un-willing to participate in the study, so the required sample size remained 220.

Data were collected from adopter and non-adopters of MHP systems in the area. A semi-structured questionnaire was used for collection of primary data from the male members of the household. The questionnaire was pre-tested in the field and necessary changes were made before starting the main field survey. To determine the effects of micro hydropower schemes on productivity of maize crop and other agricultural practices, the following regression model was used. As the dependent variable is in dummy form, therefore, binary logit model is the appropriate model in such situation (Jan and Akram, 2018; Jan and Lohano, 2021), hence, binary logit model was used in this study.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 D_1 + \varepsilon_i \text{.......... (1)}$$

Where,
Y = Use of MHP (yes =1 and 0 otherwise)
X_1 = Monthly income of the household from all sources (PKR)
X_2 = Maize productivity (Maunds)
X_3 = Area under cultivation (Jereb, 1 Jareb= 0.2 Hectares)
D_1 = Post-harvest practices (1= if Yes and 2= if No)
β_0 = constant
β_s = regression coefficients
e = error term

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

In this section, a brief description of the general characteristics of the sample respondents which are related to this study, is provided. This include age of the respondents, education of the respondents, whether MHP fulfils a households energy needs, and use of MHP for water pumping. The descriptive statistics of these characteristics are provided in Figure 2.

Age is the most significant determinant in the theory of adoption and innovation. It is evident from the existing literature that age an import indicator that forecasts the overall adoption behaviour of the household. In most of the empirical studies age is used a proxy variable for experience and income (Jan and Akram, 2018). Figure 2 shows that 59 percent of the total respondents were in the age group 18-35 years. This reflects that majority of respondents were from a relatively young age group which is encouraging from the point of view of making decision about technology acceptability. Studies show that people with young age have more inclination towards accepting new interventions (Kai, 2011).

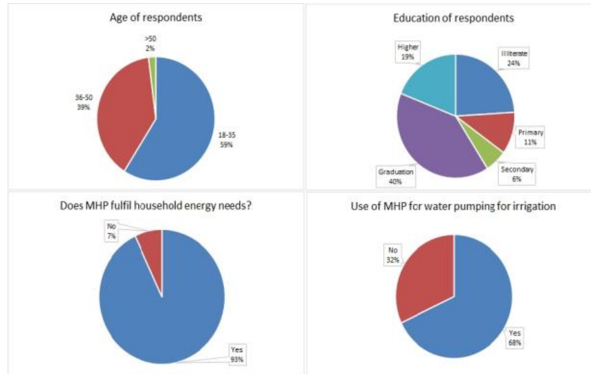

Figure 2. General characteristics of respondents

The Figure also gives details about education of respondents. Like age, education is also important for undertaking timely and positive decisions regarding use of a technology for more productive purposes (Ribeiro, 2016). The figure illustrates that majority of respondents (76 percent) were educated to different levels which again is an encouraging point regarding use of MHP for more productive purposes (Ogunmefun and Anthonia, 2015).

One of the limiting factors of agricultural productivity and other activities in developing countries is the energy poverty. Electricity from the MHP schemes play an important role in meeting the households' energy demands (Pachauri and Narasinha, 2013). The Figure shows that 93 percent respondents confirmed that electricity from MHP fulfils their household energy demands. This implies that MHP not only plays an important role in socio-economic development of rural areas but also in agricultural development in the area. Results are in line with those of Murni *et al*. (2012) who conducted research study in Indonesia and reported that MHP plays a significant role in fulfilling energy needs of rural households in Indonesia.

The figure further shows the respondents' opinion about use of MHP for water pumping for irrigation purposes. Globally, the development of the agro-based machinery and the use of electric power for operating that machinery has been a key driver in diversifying agriculture (Faruqi, 2013). It is again an encouraging point that about 68 percent respondents confirmed that they use electricity from MHP for water pumping which is uplifted for irrigating the highland fields. This is an important development for agricultural production as most of the lands which were unirrigated could be irrigated now due to electricity available for water pumping. Using regression analysis, this study finds the effect of MHP on increasing agricultural productivity of maize crop in the area.

Descriptive statistics

Descriptive statistics of all variables (dependent and explanatory variables) used in the binary logit model are provided in (Table 1), which are self-explanatory. In case of the categorical (dummy) variables, only proportion of the Yes response has been shown.

Table 1. Descriptive statistic for the variables used in logit model

Variable description	Mean / Proportion	Std. Dev.	Min.	Max.
Dependent Variable				
User of MHP(= 1 if Yes, 0 if otherwise)	0.41			
Independent Variables				
Monthly income of the households (PKR)	20540	38023	1000	410000
Maize productivity (Maunds)	53	49.16	20	150
Area under cultivation (Jarebs)	7.23	5.88	0.4	20
Post-harvest agricultural practices (= 1 if Yes, 0 if otherwise)	.22			
N = 220				

Table 2. Estimated coefficients of binary logit model

	β	S.E.	Wald	Sig.
Monthly income of the household	.000	.000	5.055	.025
Maize productivity	.016	.004	13.416	.000
Area under cultivation	-.077	.038	3.995	.046
Post-harvest agricultural practices	.814	.701	1.347	.246
Constant	-2.487	.459	29.347	.000

Number of observations = 220
-2log likelihood value = 183.91
LR $chi^2 = 28.09$
$R^2 = .20$
Prob> $Chi^2 = 0.000$

Agriculture plays a key role in the economy of developing countries including Pakistan. In countries like Pakistan who are facing the challenges of hunger, poverty and malnutrition, and high population growth rate; the increasing demand for food has changed the new paradigm of research from traditional methods of agricultural production to modern agricultural practices (Alam *et al.,* 2018). The availability of inputs and improved agricultural practices including water for irrigation purposes increase farm productivity and thereby increase income of the farmers. Results of regression model show that MHP had a positive and significant effect on income of the farmers as shown by the p-value less than .05 (the coefficient of income as 000 does not mean zero income but actually there is some value of the coefficient after zeros. However, we have taken last 3 digits of the value). Similar results were provided by Rai (2014) who concluded that MHP has played an important role in increasing income of the rural households.

Another important variable in the model was productivity of maize crop. Modern agricultural practices are energy intensive (Kennedy, 2000). The use of water-efficient irrigation technologies are becoming more acceptable in modern agriculture. The energy costs of different irrigation systems hampers their sustainability. However, the use of renewable energies in irrigation system is a possible solution to mitigate the issue (Belaud *et al*., 2019). As a result of energy shortage, the irrigation of agricultural crops had severely affected. Micro hydropower is a smart choice for the power constraint of the irrigation and can be used for irrigation purpose (Razan *et al.,* 2012). With availability of energy for irrigation purpose, the crop productivity can be substantially increased. The results in (Table 2) depicts that electricity obtained from MHP has a strong and positively significant effect on increase in agricultural productivity of maize crop as shown by the highly significant results ($P<0.01$). The results are in close agreement with those of Loo (2018) who has reported that the use of MHP has helped the local farmers to increase their agricultural production to meet their basic food need. Increase in area under cultivation is another important variable used in the fitted model. Access to electricity due to MHP has important implications for increase in area under cultivation for maize as well as other crops in the research area. The negative sign of the variable implies that, in this particular model, area under cultivation was not increased due to MHP schemes in the area. Water reservoirs all over the world serves two function i.e. the hydroelectricity production and the release of water for irrigating the crops. The functions ensure both the energy security and food security at national and regional level. In some regions, especially in warmer climates, the hydro electricity production reduces the availability of water for irrigation and food production, so there would be a trade-offs between the two key functions of the water reservoir (Zeng *et al.,* 2017). Results in (Table 2) confirms the same as shown by a negatively significant effect of MHP on increase in area under cultivation. Similar results were provided by Zeng *et al.* (2017).

The effect of MHP on post-harvest practices, particularly pre and post-harvest handling and processing machines, was also determined in the estimated model. The energy consumption and application in agricultural practices is different in both developed and developing countries. In less developed countries much of the agricultural operations are carried out manually. These operations include both pre and post-harvest handling and processing machines. Since the modern agriculture is more energy intensive, so the role of energy becomes very crucial as an input for both production and processing in agriculture. The use of renewable energy sources lower carbon emission in agriculture. For rural agriculture sector the potential renewable energy sources includes wind, solar power and hydropower (Clement *et al.,* 2018). The availability of electricity for pre and post-harvest practices ensures use of machinery which helps in reducing losses. While a very important variable in this model, however, the results shows no significant effect of MHP on post-harvest practices in the research area.

Based on the model chi-squared value and the log likelihood value, and R^2 value, it is determined that the overall model was highly significant. This implies that electricity available through MHP schemes has important role in increasing farm productivity of maize and ultimately income of the farmers in the research area. This has important implications for agricultural development and food security in the area.

CONCLUSION AND RECOMMENDATIONS

Micro hydropower schemes have the potentials for rural electrification. Rural households use electricity for different purposes like space heating, cooking, and washing. Apart from domestic use, the electricity from micro hydropower is also used in agriculture related activities like irrigation, and post-harvest activities, which subsequently increases the production and income of the farmers. This study was conducted with the aim to identify the effects of MHP schemes on agricultural productivity of maize crop in district Shangla, Khyber Pakhtunkhwa. The results of the regression model confirm that MHP schemes has a significant effect on income of the household and productivity of maize crop in the area. Cultivated area in the research district was mostly rainfed. With the availability of electricity due MHP schemes, farmers were able to uplift downstream water to irrigate their uplands. This has significantly positive effects on agricultural productivity, particularly of maize crop, and ultimately income of the households, as shown by the highly significant regression model. The study recommends that sophisticated units of MHP must be provided and installed in a scientific way to get benefits in the form of electricity generation and its use for agricultural practices. Furthermore, it is recommended that farmers may be given awareness about modern agricultural practices. This will help in promoting sustainable agriculture in the area. Special trainings may be imparted to farmers for tunnel farming and post-harvest agricultural activities, which will enhance the livelihood activates of the farmers.

Limitations of the study

This study was conducted on preliminary basis. Due to the constraints of time and funds, the study was limited to one district of Khyber Pakhtunkhwa, Pakistan. Similarly, due to the prevailing rural culture of the study area, researcher was unable to interview female members of households. The specific hilly terrain and topography of the study area, it was not possible to cover the whole population of the selected tehsils. The study could be done in a better way in future if these limitations are overcome and if advanced statistical techniques are used for analysis.

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AUTHOR’S CONTRIBUTION

M. Ahmad: Conceptualization, data curation and analysis

I. Jan: Data analysis, discussion, referencing and proof reading

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