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The Sustainability of Rice Cultivation: Evidence from Sundarbans in India

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Abstract:
Sustainable agriculture is an essential component of economic growth and the battle against poverty worldwide. This paper attempts to empirically test the sustainability of rice cultivation in Sundarbans region, India. The results show that the sustainability of rice cultivation is threatened in this area. It seems that the existing agricultural practices need to be modified. We have identified five yield influencing factors, out of which four imperative factors such as size of the cultivated land, fertilizer cost, level of education of the farmers and income of the farmers have significant impact on rice production. Therefore, framing of policies should take into account these factors to make it sustainable.

Keywords: *Rice cultivation, sustainability, farm size, cost of production, yield influencing factors*

1. Introduction

Sustainable agriculture is an essential component of economic growth and the battle against poverty, hunger and malnutrition worldwide. Though sustainable agriculture is defined in many ways, but ultimately it seeks to sustain farmers, resources and communities by promoting farming practices and techniques that are economically viable, environmentally sound and socially supportive. In recent decades, investment in agriculture was much neglected by governments and donors alike in the developing world (Johannes F. Linn, 2012)[1]. The livelihoods of the rural people in developing countries are still predominantly dependent on agriculture, which occupies a substantial proportion of countries' land area. Land is and will continue to remain the major capital asset used in production. The magnitude of agricultural land is declining due to natural hazards such as coastal erosion, flood etc. Fertility of the soil is in many cases declining due to diverse factors such as unscientific and/or excessive use of chemical fertilizers and pesticides, and erosion of natural nutrients; it seems that existing agricultural practices need to be modified.

Global demand for food is rising because of population growth and increasing affluence. According to FAO, global food production will need to increase by over 40 percent by 2030 and 70 percent by 2050 (FAO, 2009). Rice is the most important food crop of the developing countries. The livelihoods of over one billion people depend upon rice cultivation and more than 3.5 billion people depend on rice for more than 20 percent of their daily calories globally. However, global rice cultivation area is declining due to land conversion, salinization and increased water scarcity[2]. In India, it occupies about 24 percent of gross cropped area of the country and contributes 42 percent of total food grain production and 45 percent of total cereal production of the country. The average productivity of rice (2.2 tons/hectare) in India is much lower than the global average of 2.7 tons/hectare. India needs to produce 120 million tons of rice by 2030 to feed its one and a half billion plus population by then (Adhya, 2011). Therefore, sustainable rice cultivation is a significant challenge for Indian Governments.

In this perspective, we attempt to empirically test the sustainability of rice cultivation in Sundarbans region, India. This paper identifies some yield influencing factors of rice production.

2. The Study Area and Sample Design

The Indian Sundarbans is located in the North and South 24 Parganas districts of the state of West Bengal with 19 administrative blocks between $21^{0}30'$ - $22^{0}15'$ North Latitude and $88^{0}10'$ - $89^{0}10'$ East Longitude. It comprises six administrative blocks in the district of North 24 Parganas and 13 administrative blocks including Sagar Block in South 24 Parganas district. Nearly 4.5 million people live in the Sundarbans (Census of Indian, 2011). Study area of this paper is the *Sagar Block* in Indian part of Sundarbans. It is the largest Island of the Sundarbans deltaic complex. Population density will increase in future due to growing population, migration from neighbouring islands and loss of land area. Sagar has been losing its natural resources due to coastal flooding and unsustainable consumption patterns of the people.

The population depends on agriculture, aquaculture, prawn seed collection and pisiculture. Some also depend on seasonal tourism / pilgrimage at "Kapil Muni" temple during the annual fair at Gangasagar in Sagar Block. Pilgrims come every year and local people earn their livelihood from such tourism directly or indirectly. Apart from rice, crops grown are sweet betel leaf, watermelon, good

[1]Johannes, F. Linn (2012), "Scaling up in Agriculture, Rural Development and Nutrition", International Food Policy Research Institute (IFPRI

[2] See www.sustainablerice.org/rice_facts.html

quality chili etc. Nearly 80 percent of total cultivable land of this island is coastal low land. Due to presence of many constraints such as salinity, impeded drainage, lack of irrigation potential and communication problems which impede marketing of produce, most of the areas are mono-cropped.

Sagar Island is the largest Island of the Sundarbans deltaic complex, which is located in our study site *Sagar Block*. One of the major challenges in Sundarbans region is that what can be a good adaptation strategy. People have migrated from other inundated islands and settled in Sagar Block. State Government has declared Sagar to be a '*Model City'* recently. Therefore, Sagar Island provides a useful case study.

This study used both qualitative and quantitative data collected from primary and secondary sources. The study is conducted in five villages of Sagar Block, Indian Sundarban. All the villages in Sagar Block are categorized into five distinct zones, namely northern zone, southern zone, eastern zone, western zone and central zone. From each zone, one representative village is chosen. After village selection, all the households in each village are divided into two groups, namely, poor and non-poor families through focus group discussions (FGDs). Finally, 15 households (equal weightage on both poor & non-poor families) from each village are selected. Rice cultivation is the main/supplementary livelihood of those selected families. Required household data are collected from selected households based on predesigned questionnaires.

3. Methodology

Our hypothesis tests the sustainability of rice cultivation in the Sundarbans region, India. To test the economic viability of rice cultivation, first we identified relevant inputs of rice production by farmers in Indian Sundarban. After that total cost of rice production of the farmers is calculated by multiplying quantity of relevant inputs used by the farmers for rice production with per unit prevailing market price of the inputs and then finding the sum of these products. Here we consider only variable costs of rice production. Total costs are divided into six groups— labour cost, seed cost, fertilizer cost, irrigation cost, land preparation cost and marketing cost.

3.1. Labour Cost

Labour is very important part of rice cultivation. Its cost is very important in total cost of rice production because rice cultivation is labour intensive. Labour cost is the sum of all wages paid directly or indirectly to labourers for their work in production.

3.2. Seed Cost

Seed cost refers to those costs incurred in the purchases of seeds and plants at the prevailing market prices.

3.3. Fertilizer Cost

Fertilizer cost refers to those incurred in the purchase of manure, chemical fertilizer and pesticides at the prevailing market prices.

3.4. Irrigation Cost

Main source of irrigation is pond and canal in this area. Irrigation cost refers to those incurred in the purchase of water for cultivation at the prevailing market price.

3.5. Land Preparation Cost

Land preparation is important to ensure that the rice field is ready for planting. The average land preparation cost for rice cultivation is relatively higher than rural West Bengal due to frequent use of power tiller for land preparation to reduce soil salinity and limited use of indigenous wooden plough in this area.

3.6. Marketing Cost

The marketing cost for rice cultivation is the amount of money the farmer spends on marketing activities such as moving goods to a customer or points of sale. The marketing cost is much lower than other costs of production in this area.

Finally, we use a standard formula to calculate total profit of the farmers in this area. Technically,

$$\boldsymbol{\pi_i = (Q_i \times P) - \sum_{i=1}^{n} (q_{ij} \times p_j)}$$

Where,
n = Number of observations
π_i = Total profit (in Rs.) of the i-th farmer
Q_i = Total output (in kg) of the i-th farmer
P= Output price (in Rs./kg)
$Q_i \times P$ = Total revenue of the i-th farmer
q_{ij} = Amount of j-th input of the i-th farmer
p_j = Price of the j-th input (j = 1, 2, . . . , 6)

To identify the yield influencing factors, we construct a log-linear model. This model shows the relationship of yield, Yto land size (LND), share of family labour in total labour (LAB^f), fertilizer costs (FER^{cost}), level of education of the farmers (EDU) and income of the farmers (INC) is expressed as follows:

$$Y = f(LND, LAB^f, FER^{cost}, EDU, INC)$$

All these input costs have to consider as per bigha[3] costs. *Landsize* is hypothesized to be inversely related with average rice production due to marginal farmers using intensive farming methods such as greater use of fertilizer, water etc. *Share of family labour* is hypothesized to have positive impact on yield as a larger use of family labour improves the quality of work. F*ertilizer cost* is expected to have positive influence on yield.*Level of education of the farmers* is an important determinant of yield. It is hypothesized to be positively related with yield due to education of the farmers being positively related with technical efficiency and knowledge about the optimal fertilizer and pesticide dose. When number of farmers in a household is more than one we take the median of the education levels (years of schooling) of different farmers. I*ncome of the farmers* is hypothesized to have negative impact on rice yield. High income families are not intensively involved in rice cultivation. They are more interested in investing in cash crop such as betel leaf as return on investment in rice cultivation is much lower than that of cash crops. In some cases, we find that agriculture is their secondary occupation and they have some other non-farm business.

Finally, cross-section data are analyzed using log-linear regression model to separate the marginal effect of five yield influencing factors in this area on rice yield per bigha. Technically,

$$Ln(Y_i) = \beta_0 + \beta_1 Ln(LND_i) + \beta_2 Ln(LAB_i^f) + \beta_3 Ln(FER_i^{cost}) + \beta_4 Ln(EDU_i) + \beta_5 Ln(INC_i) + \epsilon_i$$

Where, β_0 = Constant term

ϵ_i= Error term, which is normally distributed with mean zero

In this model, we transform all the variables (both dependent and independent variables) into log-linear form. Finally, an OLS regression has been applied and the marginal effects are reported in Table-3.

4. Results

In this section, we discuss the results of our investigation. The primary information was collected from 75 farmers but only 73 were valid for final analysis due to outlier nature of certain information. Rice is sown mainly thrice a year: Aus, Aman and Boro rice. Our study site Sagar Block produces Aman rice mainly. Aman rice is cultivated in the rainy season (July – August) and harvested in winter. Therefore, we attempt to empirically test the sustainability of Aman rice cultivation.

Land size, L (in Bigha)	Share of population (in %)	Yield (in kg)	Share of family labourer (in %)	Average cost of chemical fertilizers (in Rs.)	Average land preparation cost (in Rs.)
Upto 1	35.1	400	60	800	640
1 < L ≤ 3	29.7	350	55	450	550
3 < L ≤ 5	20.3	300	40	350	470
5 < L ≤ 7	9.5	270	25	360	410
Above 7	5.4	250	7	375	385

Table 1: Change in productivity across farm size

Table-1 reports the change in productivity across farm size in the Sundarbans region, India. Table-1 shows that most of the farmers in this area are marginal farmers (Land size ≤ 1hectare). Farm size is inversely related with rice productivity. That is marginal farmers are more productive than small and large farmers because marginal farmers use intensive farming methods such as greater use of fertilizer, water etc. On an average, lower segment of marginal farmers (Land size ≤ 1 bigha) produce more rice of 400 kg/bigha than large landholding farmers of 250 kg/bigha. Table-1 shows, average land preparation cost and chemical fertilizer cost for rice production decreases with the increase in the size of the farms. Small landholding farmers' (Land size ≤ 1 bigha) chemical fertilizer costs for rice cultivation are high (Rs. 800 per bigha) compared to others. Likewise, average land preparation cost of the small landholding farmers for rice cultivation is much higher (Rs. 640 per bigha) than large landholding farmers (Rs. 385 per bigha). Soil salinity is a vital problem in this area especially after severe cyclone 'Aila'[4]. The surge water did not flow back into the river or Bay-of-Bengal due to lack of proper drainage system. As a result, a thick layer of salt was deposited in the top soil of cultivated land, which reduced noticeably soil fertility in the Sundarbans. Therefore, proper soil management is important for rice cultivation in this area.

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[3] One bigha = 0.134 hectare

[4] Severe Cyclonic Storm ***'Aila'*** hit the Bay-of-Bengal coast of the Sundarbans region in India, on 25th May 2009.

Land size, L(in Bigha)	Total profit (in Rs.)	Total cost (in Rs.)
Upto 1	2,880	4,320
$1 < L \leq 3$	2,604	3,698
$3 < L \leq 5$	2,000	3,400
$5 < L \leq 7$	1,545	3,315
Above 7	1,216	3,284

Table 2: Change in profit and cost pattern across farm size

Table-2 reports the change in profit and cost pattern across farm size. There is a negative correlation between farm size and total cost. As the farm size becoming larger the farmers use less chemical fertilizers and family labours per bigha. Most of small landholding farmers mainly cultivate their farm land with support of their family members. Marginal farmers work very hard and use more fertilizer to produce more output because they don't have an alternative. They spend more time on weeding, soil conservation and building the irrigation systems which are a part of good agricultural practices. Therefore, small landholding farmers enjoy higher yield and their profit is comparatively higher than other landholders. But the per capita productivity of small landholding farmers is relatively lower than large landholding farmers. The finding of this study indicates inverse relationship between farm size and profitability.

Dependent variable: rice production; Adjusted R-square: 0.57; F-test: 20.38***	
Ln(LND)	- 0.3*** (0.05)
$Ln(LAB^{f})$	0.04 (0.035)
$Ln(FER^{Cost})$	0.13** (0.05)
Ln(EDU)	0.24*** (0.089)
Ln(INC)	- 0.13* (0.07)
Constant (β_0)	5.46*** (0.71)

Table 3: Results from regression analysis

The standard errors are in parenthesis; ***, ** and * indicates significant at 1%, 5%and 10% levels, respectively.

From table-3, we find that four variables such as land size (LND), fertilizer cost (FER^{cost}), level of education of the farmers (EDU) and income of the farmers (INC) are significant with predicted sign out of five independent variables. First and third variables are significant at one percent level, second variable is significant at 5 percent level and last one is significant at10 percent level. Only one variable share of family labourer (LAB^{f}) is not significant.

Land size is inversely related with yield; as marginal farmers use intensive farming methods for rice cultivation. Fertilizer cost is an important variable of rice production. It has positively impact on yield. Soil fertility was markedly reduced in this area particularly after Aila due to soil salinity (Debnath 2013)[5]. Therefore, to increase soil fertility the farmers use more fertilizer with organic matter, which increases productivity in rice farming. Level of education of the farmers has positive impact on rice production. Farmers with high level of education are more knowledgeable about the proper dose of fertilizer use and good agricultural practices. Therefore, educated farmers produce more output compared to others. Level of income is another important variable of rice cultivation. High income families are not intensively involved in rice cultivation. They are more interested in investing in cash crop such as betel leaf or some other non-farm business because return on investment in rice cultivation is much lower than cash crop or non-farm business.

From the above discussion it is clear that profitability of rice cultivation is much low especially large landholding farmers due to high cost of production and low land productivity. Land productivity has markedly reduced specially after Aila. Before Aila, average production of Aman Paddy was 530 kg/bigha in 2008-2009, which reduced to 350 kg/bigha in 2014-2015. Land preparation cost and chemical fertilizer cost of rice production have increased to fight against soil salinity. Therefore, economic sustainability of rice cultivation is threatened in this area.

5. Conclusion

The main objective of our study was to empirically test the sustainability of rice cultivation in the Sundarbans region, India. The results above reported indicate inverse relationship between farm size and profitability because of small landholding farmers enjoy relatively higher yield than other landholders. When, land size decreases both average cost of rice production as well as productivity increases. However, profitability of rice cultivation is much low in Sagar Block. On the other hand, the magnitude of agricultural land is declining due to natural hazards such as coastal erosion, flood etc. Fertility of the soil is in many cases declining due to diverse

[5] Debnath, A. (2013), "Condition of Agricultural Productivity of Gosaba C.D. Block, South24 Parganas, West Bengal, India after Severe Cyclone Aila", International Journal of Scientific and Research Publications, Volume 3, Issue 7

factors such as unscientific use of chemical fertilizers and pesticides, and erosion of natural nutrients. So, it is clear that the sustainability of rice cultivation is threatened in this area. Therefore, the existing agricultural practices need to be modified.
Our study also identified five yield influencing factors. From Table-3 we find that four imperative factors such as size of the cultivated land, fertilizer cost, level of education of the farmers and income of the farmers have significant impact on yield. Therefore, framing of policies should take into account these factors to make it sustainable.

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