Endogenous Uncertainties of Agricultural Production Yield

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Abstract

Bangladesh is an emerging Asian country. Most of the people are involved in agriculture, but the country still finds difficulties feeding its large population. A good managerial system is still lacking in the agricultural field. That is why agricultural developments do not find sustainable growth. Endogenous uncertainties are a big issue that is affecting the agricultural system of Bangladesh over the centuries. Lots of criteria and sub-criteria are the reason behind it. Often farmers find difficulties that which criteria affecting most. Finding and solving vital criteria can increase productivity significantly. Analytical Hierarchy Process (AHP) helps to find out the main criteria which need to be solved at first. Thus, a good system can bring discipline and productivity in an agro-economic country like Bangladesh.

Keywords
Endogenous Uncertainties; Analytical Hierarchy Process (AHP); Agriculture; Agricultural Management.

1. Introduction
Being an agricultural country, the leading contributor to Bangladesh's economy is the agriculture sector. About 75% of the rural population and 40.62 percent of the total population is involved in agriculture. The agriculture sector contributes 14.23 percent to the country's GDP (Finance Division and Bangladesh, 2018). Rice is one of the main crops of Bangladesh. It is cultivated throughout the country. The environmental conditions of Bangladesh are suitable for the rice to grow all-year-round. Aus (pre-monsoon seasoned), Aman (monsoon-seasoned) and Boro (dry-seasoned) are the three main rice-growing season in Bangladesh. Despite a year-round production of rice, the national average rice yield is only 339.03 metric tons, which is much lower than the other rice-growing countries ((BBS) and (SID), Statistics and Informatics Division, 2018). The low production yield is due to many adverse conditions that agriculture is facing including uncertainties (both exogenous and endogenous).

Being the staple food of about 160 million people of the country, the total production of rice needs to be increased significantly for this ever-increasing population. As the total cultivable land decreasing at a rate of more than 1% per year, it seems to be a tough ask. Adequate steps should be taken to increase the production yield per unit area to meet the increasing demand.

The main objective of this study is to discuss the effects of endogenous uncertainties in rice production and recommend feasible solutions to address the issue that may help the person concerned to take effective steps that may help to increase the production yield of rice in Bangladesh.

2. Literature Review
Yield uncertainty occurs, when the quantity supplied and ordered, has a significant difference by a random amount (Konstantaras, Skouri and Lagodimos, 2018). High endogenous uncertainty exists when situational information is sparse, overwhelming, contradictory or novel(Heuvel, Alison and Power, 2013). Risk is present in all agricultural management decisions because of different sources of uncertainty, and as long as farmers have different preferences concerning risk, the choices he/she makes will be conditioned to a lower or higher degree by a risk-minimizing process (Toledo, Engler and Ahumada, 2011). Socio-economic factors, such as the predominance of small and marginal farmers and tenancy cultivation in agrarian structure, did not impede the adoption of modern rice varieties in Bangladesh. The major constraints to the adoption of rice modern varieties were, in fact, logistic factors such as a lack of irrigation facilities in the dry season and the topography, which affects flood depth and salinity of the soil in coastal

areas (Shelley, Takahashi-nosaka and Kano-nakata, 2016). About 60% of arable lands of Bangladesh are deficient in N, P, and K. Organic matter content of soils is much below the critical level of 1.5%. On average, 25-30% of irrigation water is used by crops and the rest is lost due to a faulty flood irrigation system. Farmer's low-quality seeds still meet about 95% seed requirement that is considered to be one of the major constraints to crop productivity (MONDAL, 2010).

Analytical Hierarchy Process (AHP) helps an organization to make its strategy more appropriate. Sometimes organization finds difficulties to make the appropriate decision before starting(Islam and Hasan, 2018). AHP is a very effective tool to deal with complex decisions. We are fundamentally decision-makers as our conscious or unconscious works are the result of some decisions(Moktadir *et al.*, 2019). If the decision making is too complex to take, then AHP can help to make the best decision (Paul, Chakraborty and Ayuby, 2011). It is one of the most popular methodologies for making the correct decision. Before starting the decision, we need a goal, criteria, sub-criteria, and alternatives and find out the best alternative to make the correct decision(Saaty, 2002).

In this paper, we will try to identify the main endogenous uncertainties of agricultural production yield by prioritizing the weights of criteria. All over the world, AHP is certified as an easy and effective tool that helps to make complex decisions. We took experts' opinions and analyzed the criteria before writing this paper.

3. Data Collection and Analysis

In this investigation, primary data is used for analyzing the present scenario of the production system of rice production yield. These data were collected from experts and farmers. The primary data obtained from the field survey was collected through visiting Bangladesh Rice Research Institute (BRRI), Rajshahi Regional Station. Chief scientist Dr. Aminul Islam, Ph. D (soil science) and senior scientific officer Dr. A.B.M. Anwar Uddin helped us to identify the factors and necessary information. We had also taken data from at least 50 farmers of Rajshahi district. Onsite observations and use of questionnaires and interviews were also used in the data collection process to identify the criteria and sub-criteria of rice production. Moreover, it is known through the survey that thequality of seed, knowledge, irrigation, use of technology, and socio-economic structure mainly are the endogenous uncertainties that harm the crops production system. After completing data collection, these data are analyzed to utilize in this study by computing the comparison matrix of the criteria and sub-criteria.

Factors responsible for variation in production yield (according to experts and farmers):

i. **Quality of Seed:** Seed is a key input for improving crop production and productivity. Increasing the quality of seeds can increase the yield potential of the crop andthus,it is one of the most economical and efficient inputs to agricultural development (Abebe and Alemu, 2017). Good quality of seed can increase crop production by 15-20% alone. But of the total seed requirement, only one-tenth is supplied to the farmers. As a result, farmer's low-quality seeds still meet about 90% seed requirement that is considered to be one of the major constraints to crop productivity. The seeds need to be germinated enough before sowing at the right temperature. Also, the seeds need to be pure and variety free for the desired production of rice.
ii. **Knowledge:** It is a common picture of the farmers of developing countries. Necessary information is sometimes not understood by the farmers and thus the cultivation process is not scientific and modern. Since they are mostly uneducated, they lack the technical and technological knowledge related to production. Sometimes, they do not receive the precautionary message from the authority at the right time.
iii. **Timing**: It is important to sow the seeds, fertilize them and provide irrigation at the right time. Every crop needs proper timing. The whole production maintains a fix timing schedule. Otherwise, the expected yield cannot be achieved.
iv. **Fertilization:** Farmers normally use urea in recommended doses. Sometimes theyoverdose as well. Because of high prices, they apply Phosphorus and Potassium fertilizers at the rates that are far below the recommended amount. Chemical fertilizers are not normally integrated with organic manures and farmers do not use balanced fertilizers that are necessary for high productivity.
v. **Use of Pesticides:** The use of fertilizers, quality seeds, and irrigation together cannot ensure sustainable production unless timely and appropriate measures for the management of pests and diseases are simultaneously pursued. It is important to note that the incidence of diseases and pests has lately become very severe due to the adverse effects of climate change and temperature increase. Sometimes, the

farmers use excess pesticides and insecticides which reduce the immunity of the paddy and results in dis-satisfactory production.

vi. **Irrigation:** Irrigation is one of the main problems of Bangladesh. Farmers often cannot provide sufficient water. Climate change also affecting the agricultural system because of the scarcity of water. Conservation of rainwater during monsoon is also virtually non-existent that could be utilized for irrigating crops during the dry season. Irrigation must be provided at the right time and the required rate. But due to scarcity of water in the dry season, the farmers don't get enough irrigation in due time.

vii. **Socio-economicstructure:** Since most of the farmers do not own land of their own, the land is generally leased out to them. The farmer, as tenants, does not know for how long he will be able to retain the land in his possession. He may hesitate to make any long-term improvements in the land as he may not be sure about earning the additional return from such improvements.

viii. **Use of Technology:** Some of the incurred problems (such as sowing, harvesting, fertilizing) may be overcome with the help of modern equipment. But the farmers lack adequate financial support to purchase the equipment and are carrying with the ancient processes.

4. Methodological Approach

4.1 Analytical Hierarchy Process (AHP) Analysis

The basic procedure of AHP consists of following these steps (Mahmud *et al.*, 2016). These are given below:

Step 1: Developing the weights for the criteria by
a) Evaluating a single a pair-wise matrix for the criteria;
b) Normalizing each column of the matrix and calculating appropriate priority or weights;
c) Computing and checking the Consistency Ratio (CR) by using the following equation;
computing and checking the Consistency Ratio (CR) by using the following equation

$$\mathbf{CR=} \frac{\mathbf{CI}}{\mathbf{CR}}$$

Here, **CI** = **Consistency index** = $\frac{\mathbf{Eigen\ Value-n}}{\mathbf{n-1}}$

Where the small n denotes the number of criteria. Random Consistency Index (RI) and which is taken from Table 1,

Table 1. Random Consistency Index (RI)

Criteria	3	4	5	6	7	8	9	10
RI	.58	.90	1.12	1.24	1.32	1.41	1.45	1.49

If the value of CR is less than 0.1 (10%), then the pair-wise comparison is considered acceptable. If the consistency is greater than 0.1 then this comparison matrix will not accurate. The relative importance values in the comparison matrix are determined with Saaty's 1-9 scale (Table 2), where a score of 1 represents equal importance between the two elements and a score of 9 shows the extreme importance of one element (row component in the comparison matrix) compared to the other one (column component in the comparison matrix). Saaty's table (1-9) is given in Table 2.

Table 2. The fundamental scale of absolute numbers (Saaty, 2002)

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective.
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one over another.
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one over another.
6	Strong plus	
7	Very strong importance	Activity is strongly favored
8	Very, very strong	
9	Absolute importance	The importance of one over another affirmed at the highest level.

Step 2: Developing the ratings for each decision alternative for each criterion by,

- Constructing a pair-wise comparison matrix for each criterion and each matrix containing the pair-wise comparisons of the performance of decision alternatives on each criterion;
- Multiplying the values in each row together and calculating the nth root of the above-said product; Normalizing the nth root of production values that are mentioned above to obtain the corresponding ratings and calculating and checking the Consistency Ratio (CR)

4.2 Problem Structure and Solution Methodology for AHP

Our goal is to find out the key endogenous uncertainties in crop production yield, which affect the system most. To solve this problem, we have selected some criteria and divided these criteria into subsequent sub-criteria. Considering that these criteria are independent and a hierarchical structure is constructed. The hierarchical structure is given in Figure 1, that represents the criteria and sub-criteria has no relationship or interdependency among them. Furthermore, the AHP method is used to resolve this case.

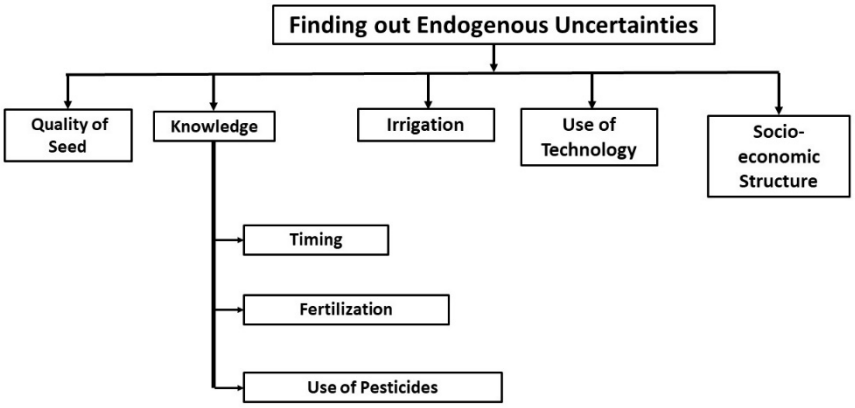

Figure 1. Hierarchy Model of Criteria and Sub-criteria

The Hierarchical structure shows that there are five criteria and three sub-criteria. Atfirst, we need to determine the priority vector for eachcriterion. The priority vector provides the priority indices for the criteria. The pair-wise comparisons of the criteria in terms of their relative importance values along with column totals are shown in Table 3.The criteria are quality of seed, knowledge, irrigation, use of technology, and socio-economic structure. In Table 4, the criteria are prioritized and ranked concerning their criteria weight. And the sub-criteria of the knowledge gap are timing, imbalance fertilization, and pesticides and insecticides.

Table 3. Pair-wise Matrix of the criteria of endogenous uncertainties of the production system of Rice

	Quality of Seed	**Knowledge**	**Irrigation**	**Useof Technology**	**Socio-economic Structure**
Quality of Seed	1	3	2	5	4
Knowledge	1/3	1	1/2	3	2
Irrigation	1/2	2	1	4	3
Use of Technology	1/5	1/3	1/4	1	1/2
Socio-economic Structure	1/4	1/2	1/3	2	1

Table 4. Priorities of the criteria

Criteria	**Priority**	**Rank**
Quality of Seed	0.419	1
Knowledge	0.160	3
Irrigation	0.263	2
Use of Technology	0.062	5
Socio-economic Structure	0.097	4

Check for Consistency:
Eigenvalue = 5.068
CI = (5.068-5)/ (5-1) = 0.017
RI = 01.12
CR= **CI/ RI** = 0.01517 = **1.51% < 10**
As the CR is less than 10%, this result is accepted. The quality of seeds contains the highest weight of 41.9%. In Table 5, a pairwise matrix is given of sub-criteria of knowledge and they are timing, imbalance fertilization, and pesticides and insecticides.

Table 5. Pair-wise Matrix of the sub-criteria of Knowledge

	Timing	**Fertilization**	**Use of Pesticides**
Timing	1	3	4
Fertilization	1/3	1	2
Use of Pesticides	1/4	1/2	1

Table 6. Priorities of the sub-criteria of Knowledge

Category	**Priority**	**Rank**
Timing	0.625	1
Fertilization	0.238	2
Use of Pesticides	0.137	3

Check for Consistency:
Eigen value = 3.018
CI = (3.018-3)/ (3-1) = 0.0009
RI = 0.58
CR= **CI/ RI** = 0.01551 = **1.55% < 10**
As the CR is less than 10%, this result is accepted. Timing contains the highest weight of 62.5%.
Computing all the comparison,priority of criterion and sub-criterion have been found and by using these priorities, the overall criteria weight is determined (Table 7).

Table 7. Computation of Overall criteria weight (OCW) of each criterion

Criteria	**Criteria Weight**	**Sub- Criteria**	**Sub Criteria Weight**	**Overall Criteria Weight**
Quality Seed	0.419			0.419
Knowledge	0.160	**Timing**	0.625	0.100
		Fertilization	0.238	0.038
		Use of Pesticides	0.137	0.029
Irrigation	0.263			0.263
Use of Technology	0.062			0.062
Socio-economic Structure	0.097			0.097

5. Result Analysis
So, from the calculations, we found out that uncertainty over 'Quality of Seed' is the criteria with the highest weight (0.419). Uncertainty over 'Irrigation', 'Knowledge', 'Socio-economic', 'Use of Technology' are the next criteria in order with the priority of 0.263,0.160, 0.097and 0.062 respectively. So, 'Quality of Seed' is the most influential in agricultural production yield.

6. Recommendations
Based on what we have analyzed and the result we found; we have figured out a solution framework that can help us solve the problem addressed increasing the production yield. Our recommendations are-

1. **Ensure the best quality seed:**If the input is good, then the output will also be good. So, farmers should cultivate the best quality seed. And make sure that the seed is at least 90% germinated, there is no variety in seeds and the pure seeds are collected for next year'sproduction.

2. **Dynamic framework for irrigation:** Steps should be taken for the conservation of rainwater so that it can be used in the dry season and a dynamic framework should be established to ensure the availability of water for irrigation throughout the year.A solar base electric motor can be introduced to ensure non-stop irrigation.
3. **Train the farmers:** The farmers should be trained regularly and the Department of Agriculture Extension should take steps to let them know the key scientific factors of rice cultivation as much as possible. They must have adequate knowledge about timing, use of fertilization and use of pesticides.
4. **Financial security of the farmers:** The government should ensure financial support to the farmers and credit should be given to them at a nominal rate. Also, the farmers should be given subsidies and must monitor properly. Also, the outrage of the intermediate media should be brought under control.
5. **Prioritizing the use of technology**: The use of technology should be given priority and technologies should be designed considering the facts of the farmers and they should be trained about the use of technology in cultivation.

7. Conclusion

From the study, we saw that the quality of seed is the most important endogenous factor in rice cultivation. Factors like irrigation, knowledge, socio-economic structure and use of technology also influence rice cultivation to some extent. We figured out the endogenous uncertaintiesand also gave recommendations. We believe if the recommendations are applied properly, the rice production yield will increase by a large margin, which can help to meet the ever-increasing demand of Bangladesh. In the future, more research can be done on other crops as well. Finding out the more root cause can help the agricultural system more disciplined and productive.

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