



Available Online at EScience Press

International Journal of Agricultural Extension

ISSN: 2311-6110 (Online), 2311-8547 (Print)

<https://esciencepress.net/journals/IJAE>

RISK MANAGEMENT TO INCREASE CULTIVATION OF HYBRID RICE FOR IMPROVED FOOD SECURITY IN BANGLADESH: A PROPOSED FRAMEWORK

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ARTICLE INFO

Article History

Received: July 11, 2021

Revised: October 10, 2021

Accepted: September 05, 2021

Keywords

Bangladesh

Food Security

Hybrid Rice

Risk Management

Framework

ABSTRACT

Bangladesh and its more than 16 million people face an imminent food crisis as the population rises and arable land decreases due to urbanization, erosion, and climate change. To prevent the mass hunger by 2050, we need to increase rice output rapidly, is to grow hybrid rice, as China did in the 1980s. This can work, but a government attempt to introduce hybrid rice in the 1990s and 2000s fell flat. Sticky hybrid rice consumption went against Bangladeshi food culture. This discouraged farmer as well as many other risks they encountered when trying to grow hybrid rice. Unlike traditional rice, hybrid rice gave no seeds for the next year, and hybrid rice seed markets were unreliable and often fake. So, fewer Bangladeshi farmers are growing hybrid rice than in 2009, as more hybrid rice is increasing exponentially. This paper considers all the risks facing by a Bangladeshi farmer trying to grow hybrid rice faces. Then it assesses what policy measures are needed to manage those risks. From this consideration, the authors develop an integrated policy to surge hybrid rice cultivation in Bangladesh to increase total rice production by 2050 by at least 83%. The authors used a qualitative survey, key informant interviewing with snowball sampling, focus group discussions, and used published materials for the research methodology. Thematic approach method using Nvivo 12 software applied for data analysis. Yet, it all implicitly hangs on changing Bangladeshi consumers' cultural preference from non-glutinous to glutinous rice, without which all of the policy changes will be too much for Bangladeshis to eat.

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INTRODUCTION

Per hectare cereal crop production has tripled in Bangladesh since independence in 1971. Yet, compared to agriculturally-developed countries, per-hectare cereals production is low in Bangladesh (Begum and D'Haese, 1970). According to World Bank data, Bangladesh can produce 4411.2 Kg cereal per hectare. In contrast, some countries like Belgium, the Netherlands,

and Ireland can produce 9050.1, 8794.1, and 8785 Kg, respectively, using the same amount of land (World Bank, 2020). China and South Korea can produce at least 2000 Kg more cereals than Bangladesh can in one hectare land area. Bangladesh can increase per hectare cereal production if farmers start cultivating hybrid rice more-extensively, using scientific management practices (Pervez *et al.*, 2017; Pervez, 2018; Pervez *et al.*, 2019).

First of all, Bangladesh needs a rapid increment of cereals yield, as Bangladesh is a country with one of the world's highest population densities (1265.19 people reside per square kilometre). Rice is overwhelmingly the staple food and the lowest per capita arable land of around only 0.048 hectares (World Bank, 2020). The Food and Agriculture Organization estimates that 0.07-hectares of arable land is required for each person with a diversified diet, including meat (FAO, 2020). Every year, nearly one percent of arable land or around 62,000 hectares of arable lands in Bangladesh are lost, decreasing due to excessive population growth (2,000,000 people per year) and changing agricultural land to industrial use (The Daily Star, 2018a).

Also, climate change phenomenon is a new headache for the country. According to the Global Climate Risk Index 2020, Bangladesh is the 7th most vulnerable country globally to climate change (Eckstein *et al.*, 2019). So agricultural output must be maximized to assure food security despite climate changes.

In Bangladesh, food security and food sufficiency are synonymous with rice production sufficiency (Pervez *et al.*, 2017; Das, 2019). Rice accounts for 75 percent of calorie consumption and even half of the total protein intake of Bangladeshis (Pervez, 2018, Pervez *et al.* 2019). Bangladeshi people consume the most significant amount of rice per capita per day in the world: 489 grams (Hossain and Yunus, 2016). Rice production total is a symbol of social status for a Bangladeshi farm family. Thus, every attempt of any Bangladeshi Government to replace rice with other crops has failed. An unstable rice price in the consumer marketplace also destabilizes Bangladeshi Governments.

To tackle the excessive demand for rice seed, after the devastating flood in 1998, the Bangladesh Government changed its agricultural policies by getting the Seed Amendment Act 1997 and the Seed Act 1998 enacted by Parliament. The new policy encouraged private seed companies to participate in the market through the importation of hybrid rice seeds (SCA, 2009).

In 1998, a total of 23,700 hectares of land was planted with hybrid rice seeds imported from China and India. The average result was impressive: there was an average of one tone increased rice yield per hectare from hybrid rice seeds over local rice seeds (Pervez, 2018). Later, a study confirmed that hybrid rice could produce a 38% increase in rice yield compared to the current best-inbred rice varieties (Salam *et al.*, 2012). Due to these

advantages, hybrid rice became popular among the farmers. In the following ten years, the area under hybrid rice cultivation increased from 23,700 hectares to 800,000 hectares (Pervez *et al.*, 2017).

However, since 2008, the popularity of hybrid rice has been dropping. Current data indicate that the area under hybrid rice cultivation is around 7.05% of the total rice cultivation (Krishi Diary, 2018). Compared to China, hybrid rice is used for nearly 60 percent of total rice cultivation (Yuan, 2014).

Professor Yuan Longping, the 'father of hybrid rice', invented third-generation hybrid rice and dreamed of planting 70 percent of all rice cultivation areas under hybrid rice worldwide (Xinhua, 2019). Professor Longping showed that the third-generation hybrid rice could produce 14.8 metric tons of rice per hectare (Xinhua, 2019). On the other hand, the average rice production in Bangladesh is 3.2 metric tons (Krishi Diary, 2020). Therefore, we have a scope to ensure the country's future food security by increasing hybrid rice cultivation in Bangladesh.

Although scholars around the world have proved that hybrid rice can increase the rice production of a country up to two to three-fold, hybrid rice cultivation is not yet popular in Bangladesh. The National Government policy, 1998 of promoting hybrid rice cultivation has failed in Bangladesh (Pervez *et al.*, 2017; Pervez, 2018; Pervez *et al.*, 2019). Many researchers have identified various risks associated with adopting hybrid rice cultivation (Shah *et al.*, 2015; Pervez *et al.*, 2017; Pervez, 2018) and it is because of these risks that the Bangladeshi farmers have turned away from hybrid rice as a potential crop. They now prefer to continue to plant local inbred rice as a safer option.

Therefore, the objectives of the research were to i) identify the risks associated with hybrid rice production in Bangladesh, which make it unwelcome to farmers, and to ii) develop a risk management framework that will enable us to manage the risks and help farmers grow more hybrid rice successfully.

METHODOLOGY

The research was based on the qualitative methodology for primary data and used the different secondary data from secondary published sources. Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were used as data collection tools for the primary data. Secondary data were collected from published and

unpublished scientific articles, State documents. The Authors used thematic analysis method and used Nvivo 12 version software for this purpose.

Key informant interviews

Key informants are individuals who, due to their position, education, experience, or earned respect in the community, know more about a given topic than most people in their community do. Key informants are essential sources for collecting valid and complete data by qualitative methods, especially in an agricultural

community, where experience produces expertise more than mere research or publication (Pervez, 2018).

Snowball sampling was used to find appropriate key informants for the study. It is easy to find the hidden sample in snowball sampling, which cannot be found otherwise (Mack *et al.*, 2011). Information for the research was collected from unstructured interview schedules from knowledgeable persons in various locations in Bangladesh, from June 2017 to January 2018. The detail of the key informants used in this study is presented in Figure 1.

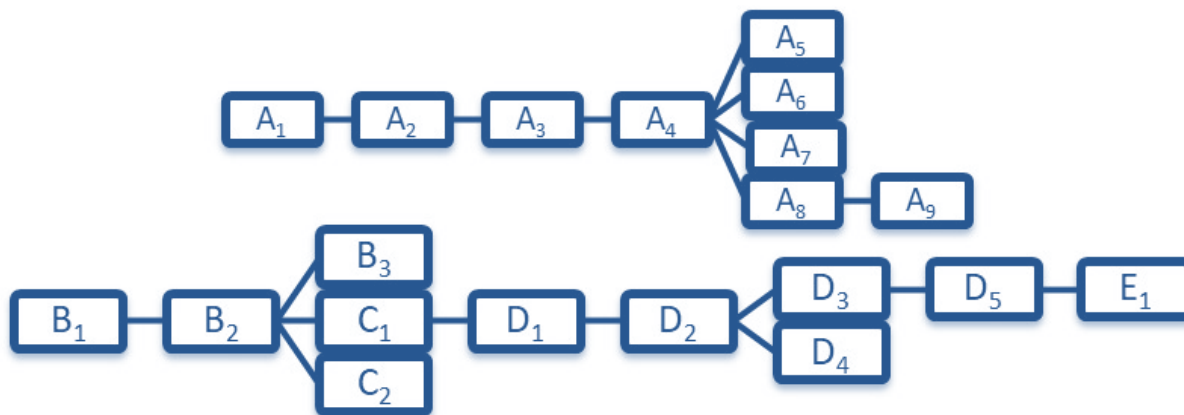


Figure 1. Snowball sampling for qualitative data collection from key informants.

Note: Only information sources: A2, A8, B2 and D1, Key informants: Hybrid rice farmers: B1, B2, B3, Seed dealers: C1, C2, Extension personnel: D2, D3, D4, D5, Rice scientists: A3, A4, A5, A6, A7, A9, University professor: A1, Seed certification specialist: E1.

Focus Group Discussion (FGD)

In this study, the researcher used FGDs to explore the study's issues from experts' and farmers' viewpoints. Each FGD was conducted with hybrid rice expert groups and farmers' groups, each with 4-8 participants. Four FGDs with experts and eight FGDs with farmers groups were arranged from June 2017 to January 2018. FGDs provide more constructed data, as several homogenous people discuss on a particular issue (Pervez, 2018).

RESULTS AND DISCUSSION

Can hybrid rice meet tomorrow's food security needs in Bangladesh?

Food security is the central issue of Bangladesh. This is mainly because of high population density and low per capita arable land. According to United Nations

estimates, the current population size of the country is around 16.76 million¹. Although different organizations estimate the future population of the country a bit differently, the minimum estimate of the country's population in 2050 will be around 200 million. Figure 2 represents the population projections of three organizations.

However, other organizations and scientists have projected the population of Bangladesh differently. For example, the UN's Population Division projected the population size of Bangladesh to 208 million in 2030 and 255 million in 2050 (UN Population Division, 2004). Some scientists expected an even higher total

¹<http://www.worldometers.info/world-population/bangladesh-population/>

population. For example, Basak *et al.* (2014) projected around 260 million, and Yu *et al.* (2010) anticipated approximately 335 million in 2050. Among the SAARC countries, the per capita arable land in Bangladesh is the

second-lowest after the Maldives. The Maldives is a small island chain with little agriculture and mainly a tourism-based economy. The density of the population in Bangladesh is also one of the highest in the world.

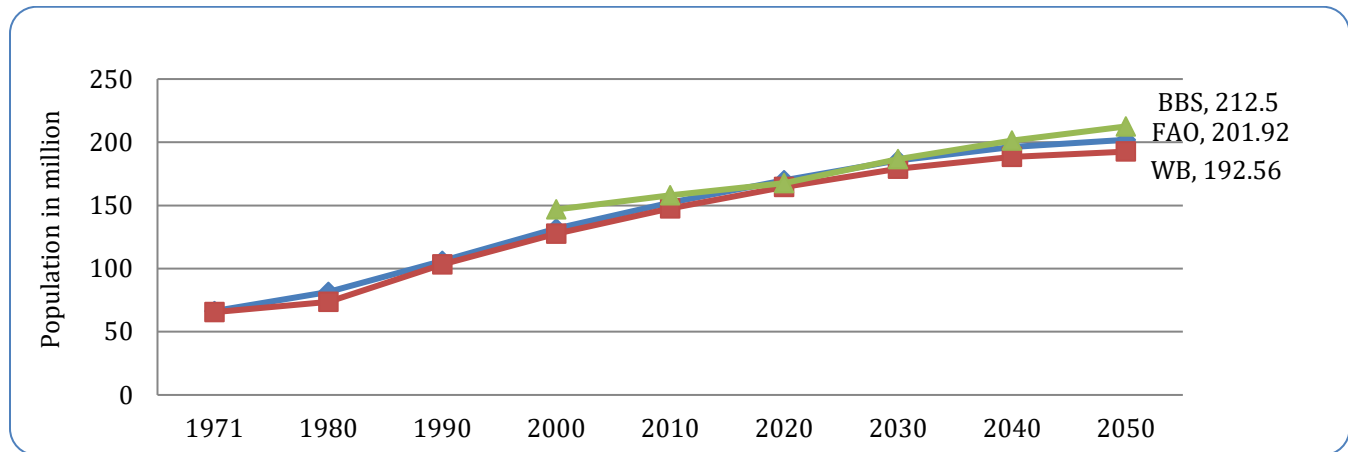


Figure 2. Present population and future projection from different sources.

Sources: Authors' calculation based on FAO (2020), World Bank (2020) and BBS (2015).

Figure 3, below, compares the per capita arable land and population density of SAARC countries. It is estimated that around one percent of the arable land in Bangladesh is converted from agricultural production to other purposes (GoB, 2010; Quasem, 2011). Current cultivable land is around 8.00 million hectares (YAS, 2019). If this trend continues, the cultivable land total will be only 5.15 million hectares in 2050 (Mainuddin and Kirby, 2015). Based on this, the author calculates the per capita arable land of Bangladesh could be 0.034 hectares per person in 2050 (assuming a continued rate of reduction of 1% / year). Figure 4, below, projects the per capita arable land of Bangladesh in 2050 by these methods described above.

Bangladesh's gross cropped area was 15.59 million hectares in 2017-18, with a cropping intensity of 195% (YAS, 2019). The total gross rice production area is 11.61 million hectares, with an average rice production of only 3.2 M ton/hectare (Krishi Diary, 2020). Thus, total rice production in 2019 was 37.15 million M tons. The current per capita rice consumption per annum is 225 kg (Mainuddin and Kirby, 2015). If the population of Bangladesh in 2050 reaches around 255 million, the demand for rice will be about 50.62 million M tons rough rice. Kabir *et al.* Kabir *et al.* (2016) assumed approximately 47.2 million M tons rice would be required in 2050. Within 30 years, on these calculations,

we have to increase rice production in Bangladesh by an additional 12 to 13.5 million M tons of clean/ milled rice by 2050 to maintain food security.

Now the question is, what will be the gross rice production area in 2050? The current rice area to Gross cropped area is 74.47% (Krishi Diary, 2020). Therefore, the total rice area will be 10.04 million hectares in 2050, based on the current proportion. Thus, the per hectare rice production needs to be 5.04 M tons/hectare. Hence, we need to increase rice production by 83.13%. How can we achieve it within 30 years? Furthermore, the impact of climate change in Bangladesh is another threat. The country has been suffering from extreme weather: from heat-waves to hurricanes and floods to drought and famine (Vidal, 2017; The Dhaka Tribune, 2018; The Daily Star, 2018b). By the year 2030, the country's average temperature will increase around 1°C, and by the years 2050 and 2100, it will increase by approximately 1.4°C and 2.4°C, respectively (IPCC, 2007). Around 8-17% of rice production will decrease in Bangladesh by 2050 (IPCC, 2007; BBS, 2008).

Therefore, it is an enormous challenge for the country to meet its food demands in the future. The only options to assure food security through (i) import food from other countries or (ii) increase per hectare domestic food production; option ii) can only be implemented by extensive planting of hybrid rice varieties.

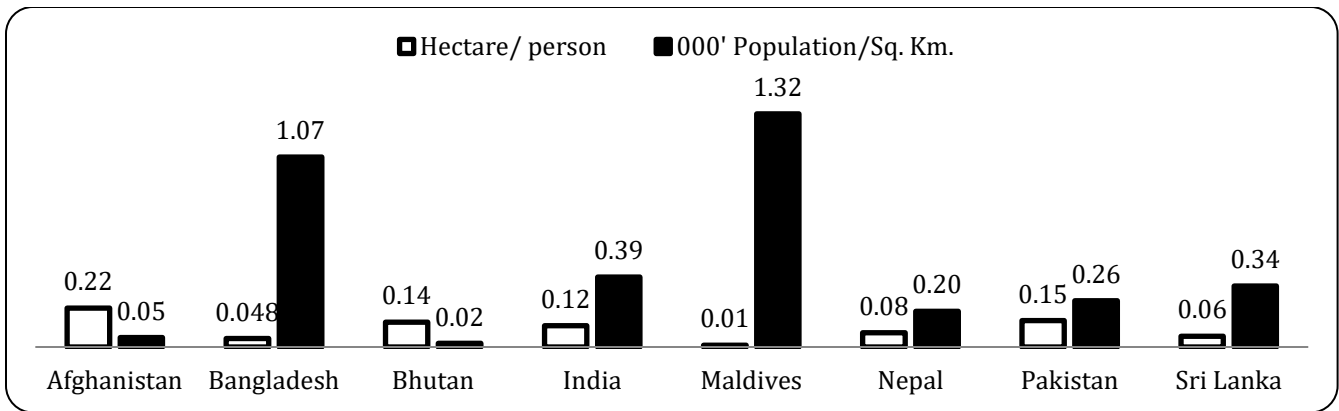


Figure 3. Per capita arable land and population density of the SAARC countries

Source: The World bank (2020); Index mundi, 2020

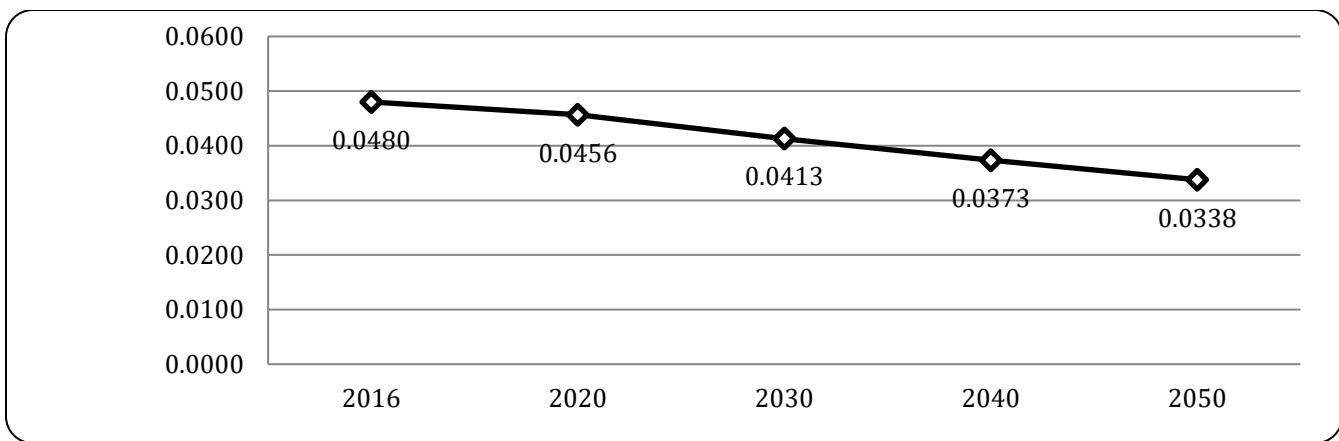


Figure 4. Projection of future per capita arable land of Bangladesh.

Source: Authors' calculation

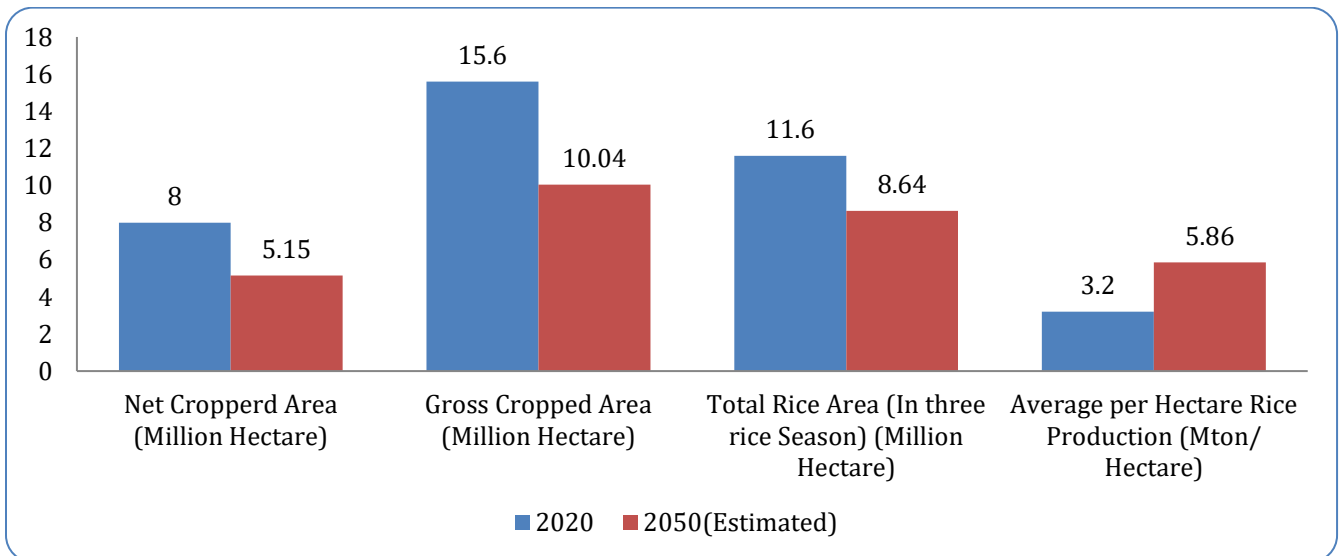


Figure 5. Net cropped area, gross crop area, total rice area, the average per hectare rice production of Bangladesh in 2020 and 2050 (projected).

To tackle temporary food crises, the Bangladesh Government has often imported food. However, reliance

on imports is not a long-term solution to the food security problem. Food imports can only be financed in an emergency, usually by incurring foreign debt. Perpetual reliance on imports when agriculture is the largest employer in the labour force is the road to national bankruptcy. What would Bangladesh sell to pay for the rice? It is not a heavily-industrialized country like Japan, Singapore or Britain, that can easily earn foreign currency by selling automobiles, banking services, electrical appliances, consumer goods, and other expensive products to pay for relying on mostly-imported food.

However, scientists have found that Bangladesh can produce all or most of the rice it needs if it can cultivate high-quality hybrid rice extensively and maintain the availability of water and land resources to do so (Mainuddin and Kirby, 2015; Kabir *et al.*, 2016; Pervez, 2018; Pervez *et al.*, 2019). The difficulty is getting the farmers of Bangladesh to trust hybrid rice again, as they began to do in the first decade of this century. That, and getting enough quality seed, water, and land to input into hybrid rice cultivation, is the only factor that will decide whether the 21st century is a time of full stomachs or empty stomachs in Bangladesh.

Therefore, the best solution to assure food security is to adopt hybrid rice cultivation as the primary means of rice production in Bangladesh (Pervez *et al.*, 2017; Pervez, 2018; Pervez *et al.*, 2019). Such a solution allows Bangladesh to meet its domestic rice demand by domestic production, keeping importation of rice as an emergency backstop to deal with temporary climate or economic fluctuations that interrupt production inevitably, and probably creates a potential for Bangladesh to become a rice exporter, as it did several

times in the first 20 years of this century. Some countries essentially feed themselves with hybrid rice. As described earlier, Bangladeshi people's staple food is rice. The average per hectare rice production in China is 6.2 tones, with extensive use of hybrids: the comparable figure for Bangladesh, with little use of hybrids, is 3.2 tons per hectare (Krishi Diary, 2020). This only is a sustainable basis for a food security policy for Bangladesh based on domestic production for domestic need.

Masuduzzaman *et al.* (2011) and BRRI (2016) showed that hybrid rice could produce around 20-64% higher yields than the top High Yielding Varieties (HYV) in both Aman and Boro rice seasons in Bangladesh. Such a substantial increase in output efficiency of land could make Bangladesh a rice-exporting country. BRRI hybrid rice- 4 is producing the most rice in Aman season in Bangladesh.

Table 1 shows 5.5-7.0 tons/hectare of the current rice variety produced in the Boro season. Let us take the midpoint of 6.2 tons/hectare. Hybrid rice produced 7.75-9.0 tons/hectare in the same season in Bangladesh, under experimental conditions. Take that midpoint (8.4 tons/hectare), and you have a projection of 35% more rice (8.4/6.2 tons/hectare) if current rice land is switched from inbred to hybrid rice, on average. However, we need 83% more rice production (as concluded earlier), so hybrid rice is a necessary, but perhaps not sufficient, strategy for achieving food security. Still, if we continue to reject the available technology of hybrid rice, we can never reach the goal because we throw away the chance to make up 42% of the shortfall in rice production. This is an illogical strategy.

Table 1. Comparison of hybrid rice and popular modern HYVs release from BRRI.

S. No.	Name of the varieties	Season	Type: Hybrid/ HYV	Yield (ton/ hectare)	Life duration (days)
1	BRRI hybrid dhann 1	Boro	Hybrid	7.75-8.5	155
2.	BRRI hybrid dhann 2	Boro	Hybrid	8.0-8.5	145
3.	BRRI hybrid dhann 3	Boro	Hybrid	8.5-9.0	140-145
4.	BRRI hybrid dhann 4	Aman	Hybrid	6.0-6.5	114-118
5.	BRRI dhann 28 (popular inbred)	Boro	HYV	5.5-6.0	140
6.	BRRI dhann 29 (popular inbred)	Boro	HYV	7.0-7.5	160

Sources: Masuduzzaman et al 2011; BRRI, 2016; Pervez, 2018

As hybrid rice is entirely new to Bangladesh, there are teething pains in using it. So, it has not been widely or

consistently adopted. The government, many private organizations, and NGOs are working to extend the

hybrid rice production area, but still, this work must be labeled "unsuccessful" in 2008-2020. The government and other actors related to this field are not well-prepared for this innovation. For example, the government does not yet have an overt policy to expand the area under hybrid rice cultivation in Bangladesh, using, for example, State purchasing of all or most of the crop, assurance of seed quality, and provision of farmer training (Pervez, 2018).

Risks In Hybrid Rice Production in Bangladesh

The concept of risk

The term risk is used in numerous scientific fields, although there is no fixed consensus to define risk (Aven, 2009). In broad terms, risk is a situation where there is an exposure to danger. According to Investopedia, financially, risk can be defined as the change of losing an amount of the outcome of an investment. It is a probability of losing a percentage of total investment².

Risk of cultivating hybrid rice in Bangladesh

In Bangladesh, hybrid rice cultivation is not established. Yield is unpredictable. Farmers sometimes get higher yields but not the desired level. Farmers sometimes have to sell their crops at a net loss, and they are mostly poor, so this can cause them to sell their land and drive them into the cities penniless. The high fluctuation of yield and market price indicates clearly that hybrid rice production is a 'risky business' (Pervez *et al.*, 2019). On the other hand, inbred rice yield and market price is comparatively stable (output and price are more-accurately predictable), which means low-risk. So poor farmers feel that hybrid rice cultivation is not for them but for the rich farmers.

Environmentally-unsuitable hybrid rice for Bangladesh

Most of the hybrid varieties are imported (out of total 119 varieties, 94 come from China, 15 from India (Ansari *et al.*, 2015). Most imported hybrid rice plants are not easily-adapted to Bangladeshi environmental conditions, pests and disease. Therefore, in research, it was found that the majority of hybrid rice farmers in Bangladesh faced moderate-to-severe risk in cultivation (Shah *et al.*, 2015; Pervez *et al.*, 2017; Pervez, 2018). They found the

significant risks were coming from 'selection of hybrid rice varieties', 'insect and plant disease', 'high level of intensive care of the plants needed', 'low demand in the market (price fluctuation)' etc.

Consumer preferences not suitable for hybrid rice in Bangladesh

Chinese hybrid rice is "sticky rice" which is not the kind of rice Bangladeshis normally eat. Sticky rice is medium-grain rice and Bangladeshis eat long-grain rice. Long-grain rice is drier and takes curries better as it has little flavor of its own. In Bangladesh, rice is the main dish and meat, fish or vegetables are merely "toppings" that make it edible and enjoyable to eat. Most Chinese eat meat, fish and vegetables as a main dish, with their own flavours, and the sticky rice is a tasty side dish.

Also, in rural Bangladesh and most poor and middle-class families even in cities, women cook rice only once, in the early morning, and their family eat it all day until going to bed – three meals plus snacks. Very few people can afford a refrigerator in Bangladesh, which is a luxury for the urban elite only. Most of the time, the cooked hybrid rice becomes spoiled before dinner.

So, Bangladeshis, having bought and eaten imported hybrid rice, usually do not want to buy it again. Thus, most poor and middle-class families do not want to buy hybrid rice. Consequently, the price of hybrid rice in the market becomes lower than the price of inbred rice. This means that there is little market demand for hybrid rice, meaning low prices and that the farmer may get "stuck" with his large rice crop which no one wants to buy (McFall *et al.*, 2013; Pervez *et al.*, 2019). Increasing rice production will be of little benefit in Bangladesh if the Bangladeshis do not want to eat what is produced. Housewives will believe that they are being given an ultimatum of "eat what you don't like or starve".

During harvest season, a lot of inbred varieties become available in the market because most of the harvested rice (92.95%) is inbred or conventional rice (Krishi Diary, 2018). Hence, the demand for hybrid rice disappears completely. This is mainly because of the poor cooking quality of hybrid rice (Spielman *et al.*, 2016; Pervez *et al.*, 2017). Bangladeshis do not like or want hybrid rice, particularly when consumers can be satiated with inbred rice. Researchers in India also identified a similar risk due to 'poor cooking quality' (Nirmala *et al.*, 2013) and 'poor grain quality' (Nirmala and Suhasini, 2013). However, these authors were not

²<https://www.investopedia.com/terms/r/risk.asp>

finding poor cooking quality but rather a perception among buyers that the cooked hybrid rice was not consistent with south Asian food culture. The ordinary south Asians in the market lacked the vocabulary and context to talk about the cultural issues, which they thought everyone understands. They could not conceive the people to be wrong, so they perceived the rice to be wrong.

Pest Problems

A key informant from Bangladesh Rice Research Institute (BRRI) described, during data collection:

Some diseases, like Sheath blight, Bacterial leaf blotch (BLB) and Blast in boro season, or insects like Stem borer and Brown Plant Hopper (BPH) are very common in a hybrid rice field. Therefore, during cultivation, we have to have the necessary prerequisites [to protect] against the said pests. (a rice scientist, BRRI, 27 December 2017).

So, pest infestation, which destroys the crop and causes the farmer's yield to be lower than planned, is a real risk for hybrid rice production in Bangladesh.

Low Seed Quality

Another main risk of hybrid rice production comes from low-quality seed and smaller quantities of quality seed than is required. Private companies mainly control the hybrid seed market in Bangladesh. Private companies exist to maximize sales: they have not cared whether the seeds grew rice or whether the purchaser knew how to use them. Many traders, who are not agriculturalists and know little about the seeds, open temporary shops during the rice season (Pervez *et al.*, 2017). The traders often cheat farmers as the seed monitoring system in Bangladesh is very weak. These fake seeds create a high probability of lower yield so total failure of the crop is a real risk.

A farmer explained during an FGD:

If you ask the farmer about the seed quality of hybrid rice, I think most of them will say, the quality of hybrid rice is not good because most of the farmers have some bad experience with low yield, bad germination etc. In our village, many farmers, therefore, no longer cultivate hybrid rice (Fazle Ali (34), 9 July 2017).

Bangladesh Agriculture Development Corporation (BADC), in cooperation with the Department of

Agricultural Extension (DAE), State trading corporations, supplies a small quantity of hybrid seeds to the farmers, at a comparatively lower price than do private companies. However, BADC and DAE suffer from a lack of experienced personnel to support hybrid rice farmers which create risks like the 'uncertainty of extension support' during cultivation (Pervez, 2018). Also, the State's total supply of high-quality rice seeds only can serve a small percentage of the total of farmers who could plant hybrid rice.

Farmer Ignorance/Lack of Support

During a focus group discussion with experts at hybrid rice division in BRRI (7 July 2017), a scientist of the division said to the author:

Hybrid rice is a sensitive crop. Yield may decline if you make a mistake at any stage, from seed sowing to harvesting. Therefore, we recommend a supply of a booklet, including production methodologies, with the seed bag. On the other hand, the reason behind the lack of knowledge of farmers is because of the low-level knowledge of our extension agents. If you go to the villages in Bangladesh, you find many farmers' field schools (FFSs) based on rice cultivation: but never find any school based on hybrid rice cultivation. Currently, we feel the necessity of training extension agents about production technologies of hybrid rice, but due to low manpower, we are unable to arrange this training at this moment.

Similar findings have also been found in other studies, e.g. Salam *et al.* (2012) found farmers have some basic knowledge in high yielding varieties (HYVs) cultivation, but 98% of farmers surveyed had no scientific knowledge about hybrid rice farming. Other researchers also found similar findings in Bangladesh (Spielman *et al.*, 2013; Shah *et al.*, 2015; Pervez *et al.*, 2017).

Many farmers do not know the technologies regarding hybrid rice farming. Many farmers do not even know that the seeds of hybrid rice cannot be kept for next year's planting, like the seeds from inbred long-grain rice. Consequently, there is some evidence that farmers planted hybrid rice seed from the first year in the second year and made severe losses. It was found that about 98% percent of the farmers in Bangladesh were suffering due to lack of knowledge about hybrid rice cultivation (Salam *et al.*, 2012). Low level of expertise in

farming and crop creates many risks.

Due to low support, farmers do not want to adopt the innovation of hybrid rice production. A few innovative farmers are adopting hybrid varieties, but they are suffering due to lack of knowledge of hybrid rice production techniques. Thus, they are continuously facing risks in their cultivation practices, marketing etc.

Risk management of hybrid rice production in Bangladesh

Therefore, it is essential to find out the key risks associated with hybrid rice production in Bangladesh and to design risk management strategies for the farmers. Table 2 denotes different risks inhibiting rapid adoption of hybrid rice in Bangladesh, identified from the interviews in the study. In the Table, the researcher also acknowledges the risks identified by other published researchers.

Hybrid rice production is not like the production of other crops. It is a one-way process. Farmers produce the seed for most crops as part of harvesting the previous year's crop, as most agricultural plants naturally produce seed. Thus, the seed to-seed production is like a cycle, which we get from nature's "production" of new plants.

For hybrid crops, seeds are generally produced by seed companies because, by definition, these seeds are not natural. They are the result of human intervention in the genetics of plants. To produce next year's crop of hybrid rice, the farmer must acquire new seeds from somewhere, private seed companies or the State, as last year's crop has left him nothing to plant.

To plan a massive hybrid rice extension and risk management framework, we need to identify the origins of the risks in the hybrid supply chain. Then we can develop a risk management framework to break the progress of the risks from origin to farmer. Figure 6 describes the sources of hybrid rice risks in Bangladesh. Secondly, to create a hybrid rice risk management framework, the existing Research-Extension-Farmers (REF) linkage, through the Ministry of Agriculture is an asset which must be utilized in our planning. The REF linkage is recognized in the national agricultural policy (Quayyum, 2006) as the means for utilization of new technologies from research by farmers in the fields, with the extension service as the communication link for transmitting researchers' discoveries to the farmer and, in theory, feedback to the researchers from the farmer on the practical effects of the research. But practically, the linkage is very weak (Haque, 2009).

Table 2. Hybrid rice production and the risks.

No.	Risks/ Problems	Sources
Production and yield-related		
1.	Unanticipated harvest performance	Shah, 2014; Shah et al. 2015; Pervez et al. 2017; Pervez, 2018; The Daily Star, 2018;
2.	Difficulties in the selection of a hybrid variety	Shah et al. 2015
3.	High production cost	Shah, 2014
4.	Probability of massive germination failure	Pervez et al. 2017, Pervez, 2018
5.	Longer field duration than inbred varieties	Shah, 2014
4.	Excessive diseases and pests infestation	Hossain et al. 2003; Shah et al. 2015;
5.	Irrigation pump failure in the season due to power shortage	Shah, 2014; Pervez, 2018
6.	Sensitive inter-cultural practices	Shah, 2014; Shah et al. 2015; Pervez, 2018
7.	Excessive shattering loss	Shah et al. 2015; Pervez, 2018
8.	Use of F ₂ seeds by farmers foolishly by farmers	Pervez et al. 2017; Pervez 2018
9.	Hybrid rice produce empty grain than inbred rice	Shah et al. 2015;
10.	Intensive labour needed	Shah, 2014
11.	Production failure due to climatic hazards	Shah et al. 2015;
12.	Hybrid varieties are susceptible to drought	Shah et al. 2015;
13.	The unstable market of agro-chemicals	Hossain et al. 2003; Shah, 2014
14.	High irrigation cost	Pervez et al. 2017; Pervez, 2018
15.	Unavailability of quality hybrid rice seed in the sowing season	Akter and Hossain (2015); Pervez et al. 2017; Pervez, 2018; Hossain, 2019; Shah et al. 2015;
16.	Farmers' refusal of hybrid rice cultivation for excessive seed price	Hossain et al. 2003; Kabir and Rashid, 2004; Shah, 2014

Institutional or Policy Risk		
1.	The insecurity of supports from agricultural advisory services	Pervez et al. 2017; Pervez, 2018
2.	Venality in public procurement of hybrid rice	Pervez, 2018, Pervez et al. 2019
3.	Technical inefficiency of local seed companies to produce seeds	Kabir and Rashid, 2004;
4.	Research centers has insufficient molecular breeding facilities	Uddin, 2014
5.	High challenges to maintain seed quality by the companies	Kabir and Rashid, 2004;
6.	Lack of appropriate land for seed production	Uddin, 2014
Marketing risks		
1.	Low demand for hybrid rice due to the availability of inbred rice	Shah, 2014; Shah et al. 2015; Pervez, 2018, Pervez et al. 2019
2.	The low selling price of hybrid rice	Shah, 2014; Shah et al. 2015;
3.	Instability of hybrid rice price	Pervez et al. 2017; Pervez, 2018; Pervez et al. 2019
4.	Excessive presence of intermediaries in the marketing channel	Pervez 2018; Siddiquee et al. 2019; Pervez et al. 2019
5.	Instability of fertilizer prices during the rice season	Pervez et al. 2017; Pervez, 2018
Personal risks		
1.	Unsuitable for home consumption	Hossain et al. 2003; Shah, 2014; Shah et al. 2015;
2.	Crop loss due to inadequate production knowledge of farmers	Pervez, 2018
Financial risks		
1.	The financial crisis of farmers	Pervez, 2018, Pervez, 2019
2.	The dearth of credit facilities	Pervez, 2018, Pervez, 2019
3.	Difficulty in loan allocation from bank	Pervez, 2018, Pervez, 2019

The linkage among research, extension services of the Ministry, and the farmers is known as the Agricultural Knowledge and Information System (AKIS) (Rashid and Gao, 2016). In AKIS, large numbers of actors, e.g., Government organizations, non-Government organizations, farmers' groups etc. are involved.

Starting from the research end, the National Agricultural Research System (NARS) of Bangladesh comprises ten agricultural institutes (part of AKIS) managed under four Ministries (SAC, 2011). Bangladesh Rice Research Institute (BRRI) is one of these institutes, which deals with hybrid rice research in Bangladesh.

While placement of BRRI in AKIS gives AKIS, as a unit, a great potential to broaden and integrate hybrid rice research and risk management, this potential is now almost wholly theoretical. Only BRRI is involved in hybrid rice research and this institute does not communicate with the rest of AKIS about this work. BRRI has 19 research divisions. The Hybrid Rice Division has a severe shortage of human resources, with less staff than many other Divisions. To increase the adoption of hybrid rice by Bangladeshi rice farmers, Bangladesh's Government needs to invest more in hybrid rice

research, starting with proper staffing of BRRI's Hybrid Rice Division. Currently, both hybrid and inbred rice research are being conducted in the same fields. Conducting research with inbred rice in the same field, there are great risks of unplanned cross-fertilization which will weaken the advantages of each type. BRRI are currently using 5/6 feet black cloths to segregate inbred and hybrid rice research fields, but this method of isolation can still lead to contamination of the hybrid rice, which reduces its quality. In this regard, a hybrid rice specialist from BRRI stated:

Hybrid rice research in the same field with inbred rice naturally contaminates the variety, which leads to low results in our experiments. Therefore, a separate Centre for only hybrid rice research is essential to develop potential hybrid variety in Bangladesh' (7April 2018).

The scientists suggest developing a separate Hybrid Rice Research Institute/Center in Bangladesh, following China's development model for hybrid rice research, to ensure isolated hybrid rice research. Furthermore, extension agents lack knowledge of hybrid rice production, and in result the middle portion of the REF

chain collapses on this issue. This is because BRRI does not train the extension professionals. The Hybrid Rice Research Division of BRRI do not have the staff to conduct mass training for the State extension agents working in rural areas across the country. If the government were to fund the Hybrid Rice Research Division of BRRI properly as recommended above, a massive training programmer for State agricultural extension agents should be one of the first priorities on which to spend the funds. Private seed companies, which sell hybrid rice, neither research nor train in Bangladesh. Yet they could be a powerful supplement to the underfunded BRRI Hybrid Rice Division in reaching farmers and helping to solve their hybrid rice problems. Therefore, a proper hybrid rice policy should include explicit roles for both a new State Hybrid Rice Institute and the private sector, with appropriate tax or other incentives, in research, training and extension to farmers to rebuild the REF chain envisioned in State agriculture policy in hybrid rice area.

Bangladesh Agricultural Development Corporation (BADC) is the only State source for hybrid rice seed for the farmer. BADC has been marketing imported hybrid variety SL-8H from the Philippines since 2007-08 (Parvez, 2009). BRRI has developed six domestic varieties of hybrid rice but BADC, another State agency, supplements, or even, potentially, competes with BRRI with Philippine seed. Qualitative data from farmers and experts in this research suggested that BADC should do marketing BRRI seeds, not competing against them with imported seed. In creating a proper hybrid rice policy for Bangladesh, some thought should be given to the relative roles of creating new domestic varieties and importing foreign varieties, with explicit criteria under which each of these options should be chosen. To increase the adoption of hybrid rice in Bangladesh, the linkage among farmers, extension agents, and research scientists should be enriched. The enhanced linkage among the actors will reduce or manage the risks at every step-in hybrid rice extension in Bangladesh. Seed sources, both State and private, should include hybrid rice research. In expanding hybrid rice production in Bangladesh, there is more than enough work to go around for the State, the private sector, researchers and the farmers. A proper hybrid rice policy should clearly

define the role of each and assist them to cooperate in producing the best possible results for all. Qualitative data from farmers and experts strongly supported the proposal to create a specialized State Hybrid Rice Research Centre cum training Centre.

Proposed Framework

The proposed hybrid rice policy framework suggests that extension organizations, including DAE, will market the seeds to the farmers with booklets and ensure full training in needed methodologies of cultivation and adequate extension support. Thus, farmers can contact extension agents directly for help with their problems. Extension agents will be responsible for any issue related to seeds. Therefore, they must maintain a continuous relationship with the seed companies. Extension organizations at Upazila (sub-district level) will arrange field extension training for the farmers about the hybrid rice production technologies and monitor the field during the season. The mass introduction of hybrid rice-based Farmer Field Schools (FFSs) would be a suitable strategy for extension agencies in carrying out such a role.

A strong Farmers' Cooperative should be established in every Union Parishad (the lowest administrative unit in Bangladesh). The Co-operatives should arrange to sell the rice in public procurement or directly to private millers. Upazilla agriculture offices will monitor the total progress of hybrid rice cultivation and marketing at the Upazilla level.

Furthermore, Farmers' cooperatives will arrange storage facilities for the rice with Government support. If the price is low at any time, farmers will store their rice for a time and sell from the storage when they get a desirable price. Also, the government should procure rice from cooperatives with a priority. Thus, co-operatives will be popular among farmers. Furthermore, the banks should allocate loans to the farmers after getting recommendations from the Upazila Agriculture Offices (UAOs), because only the UAO knows the deserving farmers for the loan. A robust monitoring authority from the Ministry of Agriculture (MoA) will monitor the whole process. Figure 7 represents a proposed hybrid rice production and development framework.

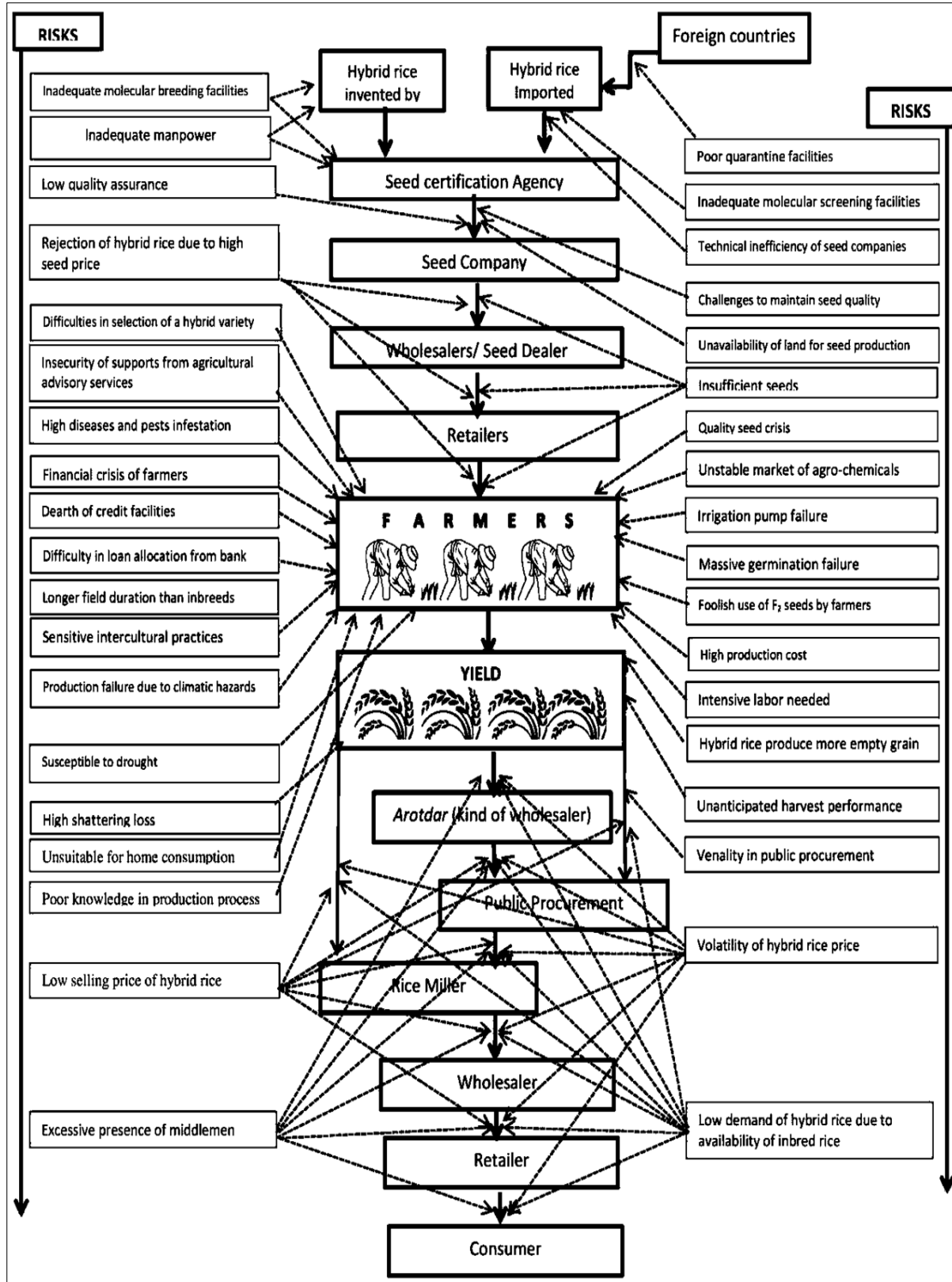
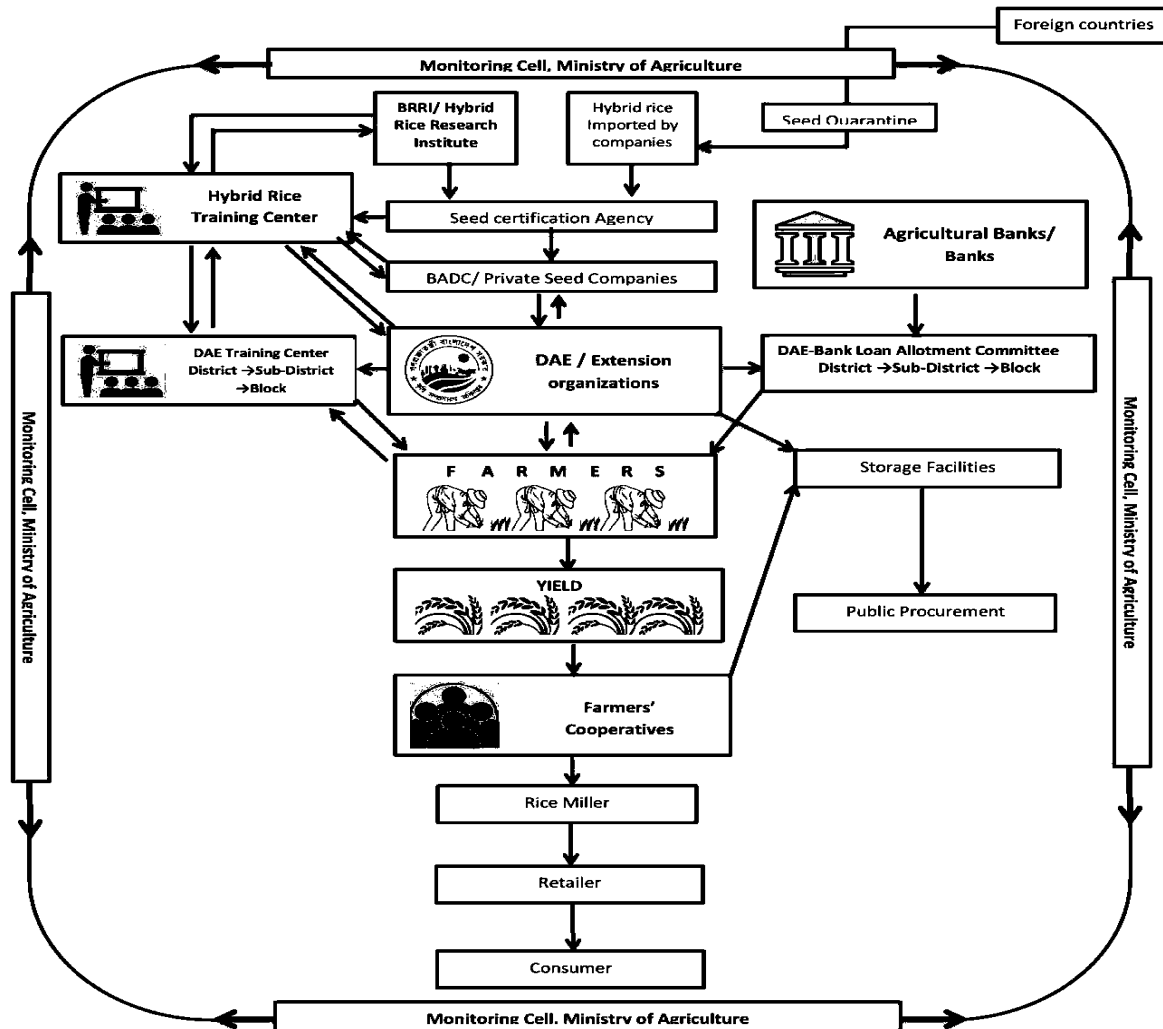


Figure 6. The risks in the supply chain of hybrid rice in Bangladesh.

Source: Original data of study.



Legend: BADC= Bangladesh Agricultural Development Corporation, DAE= Department of Agricultural Extension, SCA= Seed Certification Agency
 Figure 7. Proposed hybrid rice production and risk management framework.

Source: Original data of the study

CONCLUSION AND RECOMMENDATIONS

Bangladesh has many challenges to face regarding future food security. These begin with continuing growth in population that is already one of the densest per kilometer in the world. Added to that is the fact that arable land continues to decline under the pressures of urbanization; the conclusion here is that, within 30 years, Bangladesh needs to increase rice production up to 10-12 million metric tons. To meet such a goal, by 2050, Bangladesh needs to increase rice production per hectare to at least 5.04 Metric tons, which is 83.13% higher than the present level. Practically, it is challenging to achieve, and, currently, Bangladesh's Government has no viable policy

to achieve it. Bangladesh can only meet this ambitious goal of an 83.13% increase per hectare rice production in 30 years by growing hybrid rice in large quantities, what China has done.

Many published studies have agreed with this paper on this conclusion. Indeed, it is possible to increase production not only 83% by 2050 but perhaps as much as 200% with a successful policy to support such production with research, training, and extension, led by a new State Hybrid Rice Institute and mobilizing the private sector and the farmers, built on China's model. The authors propose:

- In Bangladesh, the government provides a subsidy for fertilizers. The government should (DAE)

provide a subsidy for hybrid rice seed similar to that for fertilizer. If the government offers a subsidized price to hybrid seeds, then the farmer will have a reason to consider hybrid rice production.

- Seed Certification Agency (SCA) should frequently collect seed samples from the market and ensure the quality of seed. To able farmers to assess the quality of seeds, frequent training on seed quality assessment should be provided through *Upazila* Agriculture Office (UAO).
- If a farmer gets much lower yield than the yield amount promised by the seed company, the company should provide compensation to the farmer. This regulation should be included in the national seed policy.
- Rice price in Bangladesh is volatile, particularly in the case of hybrid rice. The government should fix up a minimum price for hybrid rice every year. Furthermore, public procurement should give priority to buy hybrid rice.
- Intermediaries are the main culprit in hybrid rice marketing channels. The government should control intermediaries. Specific rules of law and application of the law in the field can reduce the activities of mediators. The proposed framework for risk management and hybrid rice production also recommends a healthy monitoring cell at the Ministry of Agriculture to control the marketing channel's middlemen's activities. To implement this, the government should develop farmers' co-operatives at the village level to improve their bargaining power with the middlemen on a trade union model.
- The government (DAE) should provide adequate support for seed storage for small seed companies. Furthermore, all sorts of import duties should be abolished on hybrid rice parental lines, gibberellic acid (required for hybrid rice seed production), and other necessary inputs in hybrid rice production.
- The government should enable the banks to provide rapid and easily- accessible credit for needy farmers. Who wants to enter hybrid rice cultivation? Such credit facilities should also be required of non-bank financial institutions, including NGOs.
- Department of Agricultural Extension (DAE) and other Agricultural Advisory Organizations (AAOs)

should be the only media for hybrid rice seed for the farmers as most of the seed companies do not provide any advisory services to the farmers. Many seed companies also do not ensure seed quality. If the high-quality seed companies link with the extension organisations, low-quality seed companies will have no apparent markets.

- BRRI or a new hybrid rice research institute should develop high-quality parental lines, which should be freely available to all private companies and NGOs interested in working on seed production and dissemination in Bangladesh.
- The hybrid rice-based Farmers' Field Schools (FFS) should be introduced to educate farmers about hybrid rice diseases and pests, seed-related risks, and the risk associated with farmers' poor production knowledge.
- Innovative farmers from every *Upazilla* should be trained on hybrid rice seed production under the direct supervision of BADC, BRRI, and DAE, to help hybrid rice farmers to find and use quality seeds of hybrid rice.

On paper, it can certainly be done. In practice, it would be difficult, if not impossible. China's successful hybrid rice policy was greatly aided by the fact that the Chinese people have always, for millennia, eaten "sticky" rice-like hybrid rice. Chinese people loved to eat it, so farmers loved to grow it. On the other hand, Bangladesh is a different country where people like traditional non-glutinous rice. Despite culture is not always logical, people need to be adapted with food habit in future for better food security.

ACKNOWLEDGEMENTS

The author would like to acknowledge the contribution of Jack Edward Efron, BA Econ. (Hon), PhD for review of the paper and editing the language.

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