POSTHARVEST HANDLING IN ASIA

1. RICE

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ABSTRACT

The food post-production sector is a vital component of the food system, and its development can stimulate improvements in the use of resources. One indication of the need for increased allocation of resources for research and development in the post-production system is the level of postharvest losses. Losses are attributed to a combination of factors affecting the way the rice crop is grown, harvested, cleaned, handled, dried, stored, milled, and marketed. These losses are either outright physical losses, or deterioration of quality which reduces the commercial value. Significant gains have been made in understanding the socio-economic environment under which the industry operates, and in understanding the post-harvest processes and the bio-chemical properties of the rice grain as it relates to maintaining the milled rice quality. The big gap has been in the development of technologies suitable to the conditions prevailing in Asia, and in the institutional arrangements to enable local farmers and processors to use technology to improve productivity in their operations.

ASIAN RICE FARMS

The common characteristic of Asian rice farms is that they are small, averaging only three hectares per farm household. Asia is one of the major rice producers in the world. The target beneficiary of research and development by the international and national research centers is the rice farmers with their small land holdings. The aim has been to provide them with the varieties and the technologies to produce more rice with fewer resources for an ever increasing population. More recently a new goal of research is to produce better quality rice for higher value added.

The new high-yielding varieties (HYV) have been adopted widely in commercial rice production systems, and these account for most of the yield increases. Rice production using HYV has revolutionized the industry. New technologies are required. For example, it was found that farmers needed a new method for harvesting and threshing the second crop of HYV harvested during the monsoon months. This led to the development of the axial flow thresher which can handle the new varieties under extremely difficult wet threshing conditions. This technology, developed at the International Rice Research Institute, is now widely used throughout Asia.

The different countries of Asia differ in their rice harvesting practices, according to the population density, the availability of farm labor, and whether the country is self-sufficient in rice. The level of mechanization is higher where cheap farm labor is not available. All these conditions have an effect on the type of technology required.

THE PROCESSING AND TRADING SECTOR

Once the paddy rice has left the farm, it enters the domain of the post-production sector. The people involved in the post-
production sector are not usually farmers themselves. They are entrepreneurs who invest in technology. In Asia, most work as part of a small family business. The key players in the post-production sector are the traders, the processors, the wholesalers and the retailers. These entrepreneurs are profit driven, and respond to market forces. They form a business network, and the marketing economists view this network as a marketing system. The post-production technologies are the tools of their trade.

The development of technology in Asia to store and process rice, and deliver it from the farms to the consumers, has not kept pace with the developments in the farm production sector. These lag is attributed to a strategic misunderstanding of the target research beneficiaries in the post-production sector. Public-sector research cannot seem to accept entrepreneurs as the direct beneficiary of research results. This perhaps is due to the fact that most research directors come from a culture where big corporate businesses have their own research departments.

Rice Production to Consumption Continuum

There are three distinct sectors in the rice industry: the farm production sector, the post-production sector, and consumers. In subsistence rice farming, these three sectors are combined into one. In commercial rice farming, the three sectors are distinct. The three sectors are inextricably linked, but their interests are not always complementary. In tracing the flow of the commodity from seed to the ultimate consumers, there are many stakeholders with varying and sometimes conflicting interests and requirements. If the objective of research and development is more and better food, the commercial food production and delivery system has the interest and drive for improvement.

Post Harvest Losses

A Real but Moving Target for Research

Post-harvest losses are both quantitative and qualitative. They are the result of spillage, inefficient retrieval, inefficient processing, inadequate machinery poor, operator skills, biological deterioration, and infestation by storage pests.

An awareness of unnecessary post-production losses came with the introduction of high-yielding varieties. The post-production system was not ready for the Green Revolution. The traditional technologies could not cope with the increased volume of
harvest, and handling the wet season crop was a new experience.

Various loss assessment studies were carried out by various agencies in almost all the rice growing countries. Table 1 gives an example of a loss assessment report. Invariably, the loss figures claimed are alarmingly large. The conditions under which these losses were estimated are not given. The field losses are usually actual physical grain loss measurements of grain that shattered or spilled. There are however projected losses based on potential yields. Storage losses may be based on samples where levels of pest infestation are measured. Drying and milling losses are usually derived loss estimates, or compared with control samples processed in the laboratory.

In reading loss figures, it should be borne in mind that loss assessment results are very much location specific, technology and practice dependent, and based on sample statistics. Unless the field conditions, or processing plant machinery type and condition are given, losses from different studies, or those made in different locations, or those done under different conditions cannot be compared. For example, it would be unscientific to claim gross improvements in the system by comparing loss estimates done in the 1970s with those done in the 1990s, unless the frame conditions for the loss assessment were similar. The usefulness of loss assessment studies is to make people aware of the need to allocate resources to post-production research, and to identify priority areas for research.

Fig. 2. Potential losses, post-production operations
AN ANALYSIS OF THE POST HARVEST LOSSES

The early HYV varieties shattered easily, and had short dormancy periods. Delays in harvesting caused significant losses. A crop harvested wet has to be immediately threshed and dried, or else it will germinate, discolor, or even rot. Field stacking of wet harvested rice makes the kernels turn yellow. In some countries, physical losses in the field from harvesting are almost nil. In Bangladesh, for example, gleaners will pick up every grain left in the field after harvesting. In the Philippines, ducks are let loose in the field to feed on grain left in the field.

In general, manual harvesting has lower loss levels than mechanized harvesting. However, if manual harvesting is delayed due to a lack of labor, then losses will be incurred due to shattering of overripe grain. Threshing by trampling or beating does not cause losses. However, as farm labor becomes scarce, reaping and threshing machines, or combines must be used. There is a trade-off between the need to mechanize and the higher level of losses with machines.

The inability of farmers to harvest, thresh, and dry grain was the primary cause of huge field losses during the early days of the Green Revolution. Today, the main cause of losses is the inefficient equipment used in the post-production system.

Losses in Drying Paddy

The traditional method of drying the harvested rice crop is by drying it in the sun. The crop is either left in windrows in the field to dry after reaping but before threshing, or spread out on mats or pavements after threshing. During the wet season, if there is no “artificial” drying capacity, it is not uncommon for the grain to sprout and rot before it can be dried. If there is any delay in drying, the wet grain becomes darker in color. Farmers are thus led to believe that the summer crop that can be sun-dried straight after harvesting has a whiter and brighter luster.

There has been a preoccupation in developing artificial or mechanical drying
machines to cope with the new varieties. Nowadays, most losses in drying occur because of either poor technical performance of the technology, or improper use of the technology, resulting in fissured grain. Fissured grain results in significantly lower milling recoveries.

The rice drying process has been thoroughly studied. It has been established that thermal stresses, high rates of moisture desorption, or moisture reabsorption by dried grains, all cause the rice kernel to fissure. The typical HYV medium-to long-grain Indica variety has 20% hull (or husk), and 10% bran layers. The theoretical milling yield of polished grain should therefore be 70%. State-of-the-art commercial mills, properly adjusted and working with good quality paddy, can yield 67% milled rice, with head rice (3/4 to whole grains) above 70%. Poor quality paddy that is badly fissured can lower total milling yields to as low as 60%. Much of the grain endosperm is reduced to rice flour that goes with the bran, or to brewers’ rice that is separated from the commercial milled rice output by sifters. The bran and rice flour, and small broken grains, are used as animal feed. Much is already known about the causes of fissuring. Unfortunately the basic principles of proper drying are not yet widely known in the industry.

**Losses in Milling Paddy**

Similarly, losses in the milling process are due either to inherent poor technical performance of milling machinery, or operator ineptitude, resulting in poor milling yields. An example of a milling technology that has been legislated out of existence in some countries is the Engleberg type single-pass one-step process, which is notorious for breaking the grain in the milling process and yielding as low as 53% milled rice. In 1985,
about 50% of the milling capacity in the Philippines was Engleberg mills. In Bangladesh today, the Engleberg machine is still the predominant mill. India is reported to have outlawed the Engleberg machines in favor of more efficient mills. No Engleberg machines are found in Thailand.

Reported losses in milling should distinguish between those caused by the drying process, and those due to the milling process itself. Reports should be careful to avoid double accounting for the same loss figure. If the derived potential loss in drying is 7%, milling this same rice in an Engleberg mill will result in an additional 7% loss, or a total of 14% loss in the processing plant. In the Philippines, which produces about 10 million tons of paddy, if only 50% goes through an antiquated system of this kind, 700 thousand tons of grain are lost to the consumer.

The most significant breakthrough in the rice milling industry has been the development of the husking machines with rubber rollers, which significantly reduce grain breakage. Modern milling plants now have 10 distinct steps in the process. Some setups are automated to reduce dependence on unskilled operators. The challenge is to bring this technological development within the reach of small entrepreneurs in Asia.

Losses as a Research Objective

Reducing losses as a project objective requires a careful experimental framework in order to be able to verify whether progress has been made or not. In the words of a colleague in Vietnam, loss assessment studies by themselves cannot reduce losses. A more pragmatic approach is to provide appropriate drying and milling technologies to minimize losses.

EXTENDING DRYING TECHNOLOGY INFORMATION: THE PROBLEM

The development and introduction of rice drying technology has been like chasing the rainbow with its pot of gold. The need is recognized, but investment in dryers has been slow. We know a lot about the theory of drying, and the heat and mass balance in the drying process. We understand how to dry rice grain without damaging its milling, cooking and eating qualities. However, this knowledge is not being applied.

The commercial process for drying rice uses dry, heated air as a drying medium in a forced convection system. Many physical configurations for dryers have been developed, to improve the drying process. Drying the harvested crop is a traditional responsibility of the farmers, and efforts have been directed to develop dryers for farmers to use. The general design concept is for a low-cost, dryer which is easy to build, use, and maintain.

In the Philippines, the simple flat-bed batch dryer was designed and introduced in the 1970’s. The technology did not gain acceptance with the Filipino farmers. The basic complaint was that the cost of mechanized drying was higher than sun drying. The same design concept was introduced in Vietnam. It was a hit with the farmers. In the village where it was first introduced, almost every other household built its own flatbed dryer.

What is the sociological or economic explanation? We can only surmise that in the Philippines, where rice production cannot meet demands, there is a market for wet paddy. It is a seller’s market. The demand for paddy is such that traders and millers have taken over the responsibility for drying, and therefore instead of farm dryers the need is for plant dryers with larger capacities. Vietnam, where a rice surplus is produced, is a buyer’s market. The pressure is on farmers to dry their paddy before they can sell it to millers. Farm dryers are therefore very much in demand. In Thailand, when locally manufactured rice combines came into widespread use, almost overnight a parallel demand by traders and millers for large capacity dryers developed.

Drying of paddy in artificial or mechanical dryers costs five to eight times more than sun drying. This figure however is misleading. A drying facility that is part of a processing plant makes possible the production of better quality milled rice that will sell for 5 cents more per kilogram*. A processing plant with a drying facility allows a business to buy paddy even during extended periods of rainy weather. In short, a progressive entrepreneur cannot afford not to invest in a drying facility.

In the Philippines, the realization that the
need is for plant dryers has not even dawned in some research institutions, and extension programs to promote farm dryers are still being pursued. The demand for plant dryers by millers is being met with imported units. It was an eye-opener to talk to millers who had bought imported dryers. The millers had wanted to buy a dryer, but were not aware of any locally manufactured plant dryers available that met their requirements. This is despite the fact that local research institutes in the Philippines claim to have developed many designs.

QUALITY ASPECTS OF MILLED RICE

Physical losses have been discussed. The other aspect is the economic losses due to the poor quality of milled rice. This type of loss has not been assessed, but is related to physical losses. Production of good-quality milled rice starts at the farm with good-quality seeds, and good crop care for uniform growth and grain size. The other factors that affect quality, such as mixing of varieties, heat discoloration, contamination, insect damage in storage, fissuring in drying, and breakage in milling, are controlled in the post-production operations. The same care needed to minimize physical losses applies to producing good-quality grain. The lack of appropriate technology, technical and management skills resulting in poor-quality milled rice output results in economic losses.

CONSUMER MARKET ORIENTATION

Different consumer groupings have their distinct preferences, depending on their economic status. In the Philippines, for example, where high-yielding varieties dominate in the market, it has been found that restaurants prefer fluffy grains, while rural consumers prefer sticky rice. Fluffyness or stickyness depends on amylose content, which differs according to the variety. The Philippine rice consumers’ quality criteria, in order of importance are: variety, purity, whiteness of polish, percentage of broken grains, and presence of contaminants such as weed seeds and pebbles. There is a set of official grades and standards, but the trade follows a more informal and subjective set of standards.

In the export trade, buyers set their own specifications based on market preference. Prices vary widely, depending on the quality of the milled rice. In the Philippines, for example, the National Food Authority’s imported rice for mass distribution is priced at US$0.39 per kg, while the premium grade is priced at US$0.51 per kg. Packaged and graded rice for the class A market is priced in the supermarkets at US$0.77 kg. With such a price spread, it should pay to produce the highest quality of rice.

LACK OF UNDERSTANDING OF THE RICE INDUSTRY AS A BUSINESS

Researchers have little appreciation of the rice industry as a business. It has been shown that consumers have their preferences to which the processors cater. The farm production sector supplies the raw material to the processors. This supply and demand system is, however, often distorted by political policy. Consumers want a steady supply of good-quality rice at reasonable prices. Farmers want the highest possible price for their harvest. Processors and traders have to make a living in between.

Thus, the government’s policy is to import cheap rice for consumers, maintain a high local farm gate price for paddy, and leave the processing sector at the mercy of these distorted market forces. This uncertainty provides little incentive for the private entrepreneurs to invest in more efficient processing technologies. Big business has shied away from the rice processing business in countries like the Philippines. It is public sector research, therefore, which has to provide small entrepreneurs with the technology they need.

Industrial Scale and Temperate Climate Technology

The two important characteristics of the Philippine rice industry which have prevented it from importing technology straight from industrialized countries are:

- The fragmentation of farms, so that
paddy is delivered to processing plants in small batches of different varieties and grades, making bulk handling and continuous flow systems inappropriate.

- The humid climate and the high moisture content of harvested rice. This has limited the adoption of bulk storage systems and their associated bulk handling systems.

### Bulk Systems, the Only Way to Go

Bulk systems allow more efficient handling within the processing plant, and more effective pest control. Grain in storage is a living, respiring seed that generates heat. Where there is insect infestation, the respiratory activity of the insects creates “hot spots”. Hot spots create vapor pressure differentials and convection currents so that moisture moves from hot to cold spots, further accelerating heat generation. If this process is not controlled, the wet grain will rot.

Management of bulk systems requires aeration with dry air. When the ambient air is humid, aeration requires higher air volumes during the short periods when humidity drops below 70% and aeration is possible. Aeration with humid air introduces moisture into the grain, and if this happens, fissures will develop in the grain. Research and pilot systems must ensure that bulk systems technology is feasible in the humid tropics, to control pest infestation and increase labor productivity.

### Opportunities in the Rice Business

To illustrate the business in rice, the case of a typical Filipino rice farmer and private sector processing enterprise is analyzed.

Rice farms in the Philippines are covered by the agrarian reform law. This law has effectively dismantled the feudal landlord and tenant relationship, in which the landlord owns the land and the farmer is a sharecropper. The average land holding in the Philippines today is about three hectares. This scale of rice farming is normal in most of Southeast Asia.

The farm gate price of freshly harvested wet paddy ranges from $0.17 per kilo to $0.31 per kg, depending on the supply and demand for rice in the market. Paddy pricing is very speculative, and when business intelligence indicates a shortage, prices of paddy at harvest rise quickly. The farm yields of farmers vary widely, but a farmer planting a high-yielding variety and following recommended practices can easily produce 4 mt/ha. The gross value of his production at an assumed US$0.21/kg is therefore (4 mt/ha x 3 ha x $0.21/kg x 1000) = $2520. It is estimated that it costs the farmer $359/ha to grow rice, or US$1077 for his entire 3 hectares. The farmer therefore makes a net profit of $1443 in a cropping season of four months.

A local trader assembles the harvest of farmers in an area and delivers it to the processor. For his efforts, the trader charges $0.013 per kg, or $156 for 12 mt of paddy. The price therefore of wet and dirty paddy delivered to the processor increases to US$0.223 per kg, or US$2676. The average moisture content of wet paddy during the wet season is 24%, and the grain has a purity of 95%. A kilogram of paddy with a moisture content of 24% weighs only 0.868 kg when the moisture content is reduced to 14%. After the 5% impurities are removed, there is only 0.825 kg left of clean, dry rice. The effective price of paddy to the processor is therefore (US$0.223/0.825) or $0.27 per kilogram of clean, dry paddy. On average, a good commercial mill working with a good variety of paddy will yield 65% rice, of which 80% is head rice, 17% is broken grains, 8% is rice bran, and the rest is hull.

From 0.825 mt of clean and dry paddy, a miller will obtain 536 kg of ungraded milled rice, and 66 kg of bran. The average wholesale price of ungraded rice from a high-yielding variety is conservatively placed at $0.46/kg. Rice bran sells at US$0.09/kg. Rice hull has no commercial value, although some processors use it as a source of thermal energy. The processor therefore grosses (536 kg x 0.46) + (66 kg x 0.09) or US$252.50 per mt of paddy bought. If he bought all 12 mt produced by the farmer, he makes a gross return of US$3030. The cost of the 12 mt of paddy was US$2676. Add to this the cost of processing and marketing, estimated conservatively at US$0.025 per kg of paddy bought, or US$300 for the 12 mt of paddy. The processor’s net profit before taxes is therefore (252.50 - 223 - 25) of US$4.50 per
mt of paddy bought, or US$54 for the 12 mt.

A small processor, whose mill has a capacity of 1 mt/hour (operating 8 hours a day for 200 days a year) can process 1600 mt of paddy. His net profit if he operates at 100% capacity on an 8 hour day, would therefore be only US$7,200.

**Shares in the Value of the Processed Milled Rice**

Another way of viewing the rice business is to look at the shares of the different players. Using the farmers’ three-hectare farm as a basis, with a harvest of 4 mt/ha, or 12 tons of paddy, the ex-plant value of the rice is shared as follows.

The farmer gets 47.6% of the processed value of his harvest, while the processor gets only 1.8% of the market value of the farmer’s harvest. The farmer’s income is however limited by the size of his land holding, while the processor’s capacity is limited only by his plant’s capacity, and his ability to buy paddy. The 12 mt from a single farm is only 0.75% of his 1600 mt annual processing capacity. Note that the cost of processing was based on the plant operating at 100% capacity, on a single shift.

**Farmer-based Processing and Marketing Cooperatives**

Farmers’ groups are encouraged by many governments to form cooperatives to engage in rice processing and trading. The idea is for farmers to benefit from the profits of value added activities. Some countries have succeeded with cooperatives where others have failed, so that different schemes are worth studying. Some of the difficulties relate to appropriateness of technologies used, organization, and management of resources. The lack of technical and financial systems and procedures to safeguard against conflicting interests of the farmers and their business enterprise, has been a major cause of business failure.

If the farmer with three hectares were a member of a cooperative engaged in processing and marketing, and he delivered all his harvest to his cooperative, he could expect a rebate of 1.8% of the ex-plant value of his harvest. Not much return for all his trouble. From the perspective of the manager of a cooperative rice mill, in order to keep a 1 mt/hour plant running, assuming a farmer’s marketable surplus is 30% of his harvest, he has to obtain his 1600 mt from 445 farmers, or a farming area of 1335 ha. Dealing with 445 farmers is a nightmare. It is not surprising that cooperatives in the rice business generally fail.

A good alternative is a processing plant operated by professional managers and engineers to service farmers. There has been some success with this scheme, but the concept still has to be developed further.

<table>
<thead>
<tr>
<th>Value</th>
<th>Share</th>
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<tbody>
<tr>
<td>Farm gate value of harvest</td>
<td>$2520.00</td>
</tr>
<tr>
<td>Cost of farm production</td>
<td>1077.00</td>
</tr>
<tr>
<td>Net to farmer</td>
<td>1443.00</td>
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<tr>
<td>Traders’ fee</td>
<td>156.00</td>
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<tr>
<td>(Cost of paddy to processor, $2676.00)</td>
<td></td>
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<tr>
<td>Cost of processing/marketing</td>
<td>300.00</td>
</tr>
<tr>
<td>Processor’s net</td>
<td>$54.00</td>
</tr>
<tr>
<td>Ex-plant value of milled rice + bran</td>
<td>3030.00</td>
</tr>
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IMPROVING THE RELEVANCE OF RESEARCH AND DEVELOPMENT

In recent years, the agricultural engineering profession has been accused of having minimal impact on the rice industry. An inventory of the technologies developed gave a list of more than a hundred, but only three of these have been successfully commercialized. The axial flow thresher has been the crowning glory, followed by the power tiller and the low lift water pump.

An international think-tank was convened at IRRI to review the situation. The conclusion was that agricultural engineering has contributed immensely to the development of the rice industry, but to increase the relevance of its research and development programs, it should change the way it works. Engineers should:

- Adopt a systems approach to define the problems and establish priorities;
- Learn to work with other disciplines, particularly the socio-economists, the plant breeders, and the agronomists;
- Learn to consult the end users of the technology;
- Develop cooperative programs with national research centers, and with manufacturers; and finally,
- Realize that not all problems of the industry require new or improved hardware.

Targeting Research Beneficiaries

The first step should be an in-depth study to characterize the rice industry in general and the post-production system in particular, in different operating environments. Such a study might reinforce the hypothesis that the best way to help the farmers produce more and better rice is to help them increase land and labor productivity.

Farmers have little to gain by getting involved in processing and trading their own harvest. The profit margins of rice processing are very slim. Entrepreneurs need to have economies of scale, the technology to increase milling yields and produce good quality rice, and systems to reduce production costs. Small-scale rice processing entrepreneurs are legitimate beneficiaries of public sector research.
PRIORITIES FOR RESEARCH AND DEVELOPMENT

System characterization

- To establish how farmers can benefit from higher levels of mechanization in the farm level post-harvest operations. Non-photoperiodic varieties, irrigation, turn-around time, and timeliness of operations all contribute to increased productivity, while mechanization is a key component.
- To establish optimum scales of plant capacity for rice processing entrepreneurs. Economy of scale, and compatibility of capacities of the different unit operations in a processing plant, are required for a viable business.
- The technology requirements of small-scale rice processing entrepreneurs should be established. The mill is the heart of the system, and the drying plant must allow full utilization of the mill’s capacity.
- The preferences and demands of different economic classes of consumers should be known. There are market niches which particular types of paddy and milled rice can supply.

Technology Development

- Local manufacturing industry should be given dryer designs that are modular for easy maintenance, and designs that have the flexibility to handle several varieties and grades of rice.
- We need to known more about how to produce better-quality milled rice.
- Systems and procedures for quality control programs in the rice industry should be developed.
- Rice hull should be used as a source of thermal energy, to reduce the cost of processing.
- Bulk systems should be promoted, to increase the scale of operations in Asia and improve plant productivity and pest control.
- Pest control measures in the storage systems used in Asia should be improved.
- Processing characteristics of HYVs should be evaluated.
- Milling technologies for HYVs should be evaluated.
- The level of instrumentation and automation in processing plant operations should be increased, to minimize the errors of unskilled operators.
- Computer decision support systems should be developed as a guide for plant managers and operators.
- Small-scale seed processing (drying, cleaning, grading) facilities should be established, where communities can produce rice seed to meet their own requirements.
Institutional Development

- Opportunities should be provided for training an adequate number of researchers and extension engineers
- Training programs for technicians are needed
- An industrial extension program for manufacturers should be developed.
- Linkages between processors and farmers should be developed.

CONCLUSION

Significant gains have been achieved in rice farm production, but the development of the rice post-production sector has not kept pace to take full advantage of the breakthroughs. Post-harvest loss figures are only indicators of a problem. Understanding the cause of losses is much more important. The key post-production system technologies for minimizing losses and improving milled rice quality are in drying, storage, and milling technologies.

Small-scale entrepreneurs in the post-production sector invest in technologies and are profit driven. They are legitimate public sector research beneficiaries, if more and better rice is to be achieved. Seed processing and the use of certified seeds would contribute a great deal to the production of better-quality, higher-value milled rice products.

Bulk systems are the way to improve plant productivity and pest management control.

There is very little to gain if farmers participate in the processing and trading of their rice harvest. Their best opportunity for higher incomes is to improve their yields and lower their cost of farm production by means of more efficient technologies. To provide a good processing service to farmers, professionally managed processing and trading plants would be more sustainable than farmers’ cooperative mills.

REFERENCES


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