

ECONOMICS OF USING ON-FARM AERATION GRAIN STORAGE

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ABSTRACT

A grain harvest simulation model is developed using MATLAB to examine the economics of using on-farm aeration grain storage to minimise the impact of weather damage during harvest. The comparison of return for grain production with and without on-farm aeration is simulated using 10 years (1996-2005) weather data for Goondiwindi, Queensland. The simulation result shows that the grain growers with on-farm aeration grain storage can obtain up to 8% higher return compared with grain growers without the on-farm aeration grain storage facility when grain is harvested between 16 to 22% moisture content (wet basis). At these higher moisture contents, an aerated storage with higher capacity is generally more economical than with a smaller capacity.

Keywords: Aerated storage, Simulation model, Economics, Grain

INTRODUCTION

Seasonal summer storms and rainfall during harvest period can cause serious damage and harvesting delays in northern cropping zone of Australia. Abawi et al. (1995) reported that losses due to weather damage during harvest costed the Australian wheat industry around \$30-50 million annually. Therefore, the optimisation of harvesting and postharvest management strategies to minimise the impact of weather damage and to meet the market requirements of high quality grain are the priority of the grain growers. Nowadays, on-farm grain storage and drying facility is increasingly used as a risk-management tool to overcome the problem. By having on-farm storage and drying facility, grain can be harvested earlier in the season at higher moisture content which will minimise losses of both grain quantity and quality due to weather damage, avoiding losses from shedding and lodging and allowing grain growers to blend their grain. This strategy also provides grain growers with greater marketing options. However, the long-term storage of grain in on-farm grain storage above 13% moisture content (w.b.) without aeration can result in quantity and quality loss due to insect, fungi, bacteria and mould activities. According to Bridges et al., (2005), grain stored for long periods of time is generally required to be aerated to maintain the overall quality and reduce the risk of storage losses due to insects and mould growth. The grain respiration also contributes to dry matter loss. Therefore, on-farm storage equipped with aeration system is becoming an important tool to keep grain under uniformly cool and dry conditions.

Grain aeration system is a very useful physical technique in grain preservation. Aeration is a forced movement of ambient air through stored grain to maintain the grain temperature to the desired level (Maier & Montross, 1997). The main purposes of grain aeration are to maintain a uniform temperature in the grain and to keep that temperature as low as practical (Foster and Tuite, 1982). Noyes (1990) reported that forced ventilation of ambient or refrigerated air through stored grain is necessary to maintain product quality. Grain cooling decreases biological activity in the grain ecosystem and prevents moisture migration (Muir et al., 1989). Aeration also provides farmers more control over grain quality during storage.

Strahan and Page (2003) claimed that determining the benefits gained from on-farm storage and drying facility can be quite difficult, especially when faced with variable seasons and markets. However, by using computer simulation technique, the economics of using on-farm storage and drying facility can be easily examined. Computer simulation model can also appropriately guide grain growers to purchase machinery and equipment based on their financial ability and farm conditions. Furthermore, the computer simulation model is the easiest means to calculate all of the operational costs, capital costs and benefits associated with the grain harvesting, on-farm storage,

aeration system and drying facilities. Abawi (1993) developed a simulation model of wheat harvesting and drying to examine the effect of many variables on the total cost of wheat production in northern Australia. However, Abawi excluded the aeration system in his simulation model. As the time changes, aeration system now become popular and frequently used by grain growers. Therefore, there is a need to evaluate the economic consequences of aeration system for on-farm storage.

The Wheat Harvest Simulation Model (WHSM) is being developed at USQ as a potential tool to enable researchers and grain growers to quantify and examine the various management options and strategies to effectively manage the risks associated with weather damage at harvest. In this paper, however, this simulation model is merely used to assess the viability of investment in aeration system for on-farm storage. The primary objective of this paper is to examine the economics of using on-farm aeration grain storage in grain production and harvest system.

METHODOLOGY - SIMULATION MODEL

The WHSM computer program is developed using MATLAB language. Details about the mathematical models, control values and parameters used in this paper can be found in Abawi's paper (1993) unless explicitly stated otherwise in this paper. The aeration grain storage sub-model is incorporated into the simulation model. This simulation model is simulated over 10 years (1996-2005) of weather data for Goondiwindi, Queensland. It is also assumed that the wheat reaches maturity and 30% moisture content at the beginning of the season (1st October). The results presented in this paper are averages for the above period.

Simulation Flow

Grain with moisture content of 12% (w.b.) and below is directly delivered to commercial storage. Harvested grain with moisture content exceeding 12% (w.b.) is first delivered into dryer. If the dryer capacity is exceeded, the harvested grain will be placed into an aerated storage. The aerated storage provides a buffer between harvester and dryer for the wet grain. As soon as the dryer space becomes available, the grain from the aerated storage will be transferred into it. If the aerated storage capacity is also exceeded, the harvested grain will be temporarily placed on the floor. As soon as aerated storage becomes empty, the harvested grain then will be placed into the aerated storage. Finally, dried grain which has reached 12% moisture content (w.b.) will be delivered to commercial storage.

Model Inputs

The grain price used in this paper is based on the average grain price in 2005 as provided by Australian Wheat Board (AWB), Toowoomba. The prices used are as follows: Prime Hard (\$180/t), Australian Hard (\$165/t), Australian Standard White (\$140/t), General Purpose (\$140/t) and Feed Purpose (\$140/t). The fuel cost is calculated for both Diesel and LPG using a price of \$0.85/litre and \$0.56/litre respectively. The electricity cost is calculated using an average price of \$0.10/kWh. In this paper, the crop area is set at 600 ha. The maximum harvesting time is 61 days. After this period, unharvested grain is considered as lost. The labour cost is set at \$15/hr. The working hour for labour is calculated by multiplying the harvesting and drying time with a factor of 1.5.

Harvester Capacity and Cost Model

The combine harvester with 7.3 m comb size and 10 km/hr forward speed is used in this paper. The price of harvester is calculated using the following equation:

$$C_h = 10,000 (5.95W_c - 13.70)$$

where C_h is capital cost of harvester, \$; and W_c is the comb size (width of cut), m.

Dryer Cost and Capacity Model

The dryer used in this study is based on Agridry Continuous Flow Dryers model AR1214, with 22 kW fan and 20 t/hr output rating. The capital cost of this dryer is \$92,500. According to Agridry,

dryers are rated on the basis of drying wheat from 15 to 12% moisture contents at an ambient condition of 20°C and a relative humidity of 50% using drying temperature of 70°C. For this paper, the drying temperature is set at 70°C.

Aerated Storage Model

The Aerated storage model used in this paper is classified as aeration-cooling. This model is based on Kotzur silo (GPE 8-5-35) manufactured by Modern Engineering & Construction Co Pty Ltd. The capacity, diameter and overall height of the silo are 145 tonne, 5.8 meter and 10.0 meter respectively. The aerator is assumed to be continuously used day and night, with an airflow rate of 2L/s for each tonne of grain. The cost of the aerator has included the costs of fan and motor and storage bin, but excluded the costs of other auxiliary items such as augers and concrete pads. These items are assumed to be readily available. The capital cost of aerated storage is calculated using the following equation:

$$A_s = S_s A_c$$

where A_s is the cost of the aerator, \$; S_s is a storage capacity, t; and A_c is the aerator cost per tonne, \$/t; which in this paper, is assumed to be \$140/t. In the aerated storage model, the spoilage model of Fraser and Muir (1981) is used. It is assumed that if the grain is kept within the safe storage time, no grain spoilage will take place. Otherwise, the wheat quality will be reduced from the grade of Prime Hard to Feed Quality.

The input parameter of an aeration diameter is also added. For a given aeration fan, the diameter of aerator has a significant effect on pressure drop which in turn has a direct effect on fan power requirement (Arinze *et al.*, 1994). Therefore, the required power for fan F_p , per unit inlet area of the bin floor at 50% efficiency is calculated using the following equation (Arinze *et al.*, 1994):

$$F_p = 2 \Delta P_g Q$$

where Q is air flow rate per square meter of the floor area, m/s; and ΔP_g is pressure drop of air passing through the bulk of grain. ΔP_g is calculated using the following equation:

$$\Delta P_g = \frac{2.14 \cdot 10^4 Q^2 H}{\ln(1+13.2Q)}$$

where H is the depth of grain in bin, m.

SIMULATION RESULTS

The comparison of return in grain production system between farm with and without aeration system

Figure 1 shows the comparison of returns between a farm with and without aeration system. The calculated return has not included the crop establishment costs such as planting and fertilizing. In this study, an aeration silo with a (small) 145 tonne of storage capacity is used. It can be seen that in this case, grain growers with or without aeration system will both gain the maximum return if grain is harvested at 16% moisture content (w.b.). However, the simulation result also shows that grain growers with an aeration system would obtain 2% or \$6.5/t higher return than grain growers without an aeration system if grain is harvested between 15 and 22% moisture contents (w.b.). This return will continuously decrease for both systems when grain is harvested from 17 to 22% moisture contents (w.b.). This is because, at higher moisture contents, grain is too wet so that the aeration system will not be unable to treat it. In fact, grain at moisture content higher than 15% (w.b.) is not suitable for storage and is liable to heat and become ruined within days/weeks of storage. Therefore, grain at moisture content of 15% (w.b.) and above should be dried as soon as possible using suitable drying facility.

At lower grain moisture contents from 12 to 14% (w.b.), having an aeration system is less economical because at these low grain moisture contents, the drying process is faster. Therefore, dryer has enough space to dry all harvested grain in time before the deterioration of grain quality occurs.

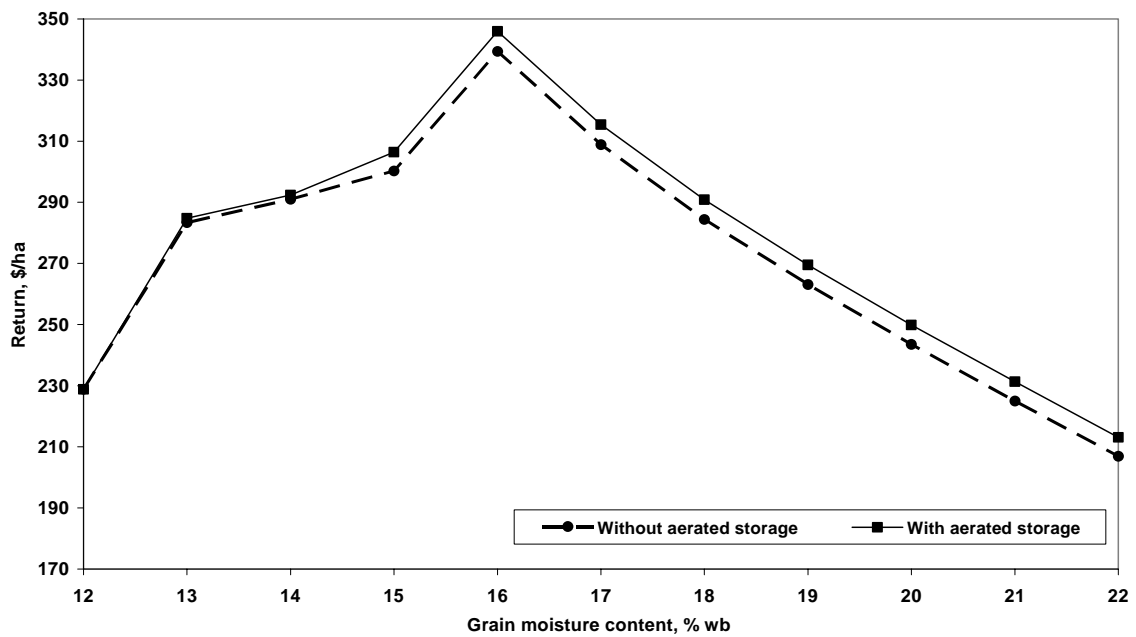


Figure 1: The comparison of return in grain production system with and without aeration system

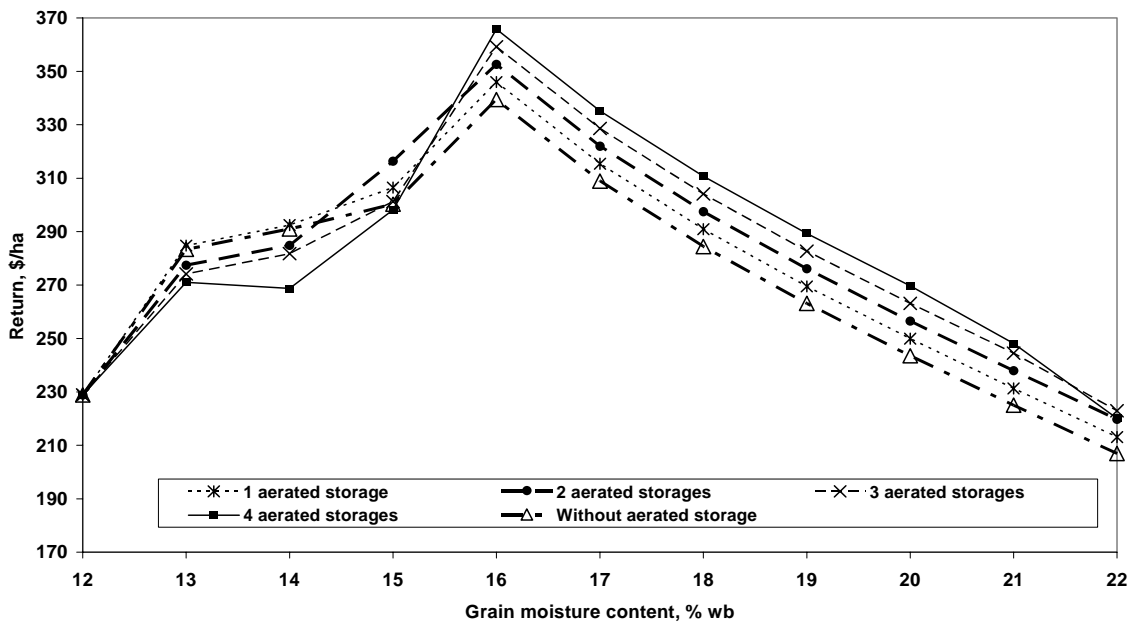


Figure 2: The effect of different number of aerated storage on return

Figure 2 shows the effect of number of silos on return. The result shows that the optimum harvest moisture content for all systems mentioned above is all at 16% moisture content (w.b.). A 2% increase of return is achieved when each additional aerated silo is added. At lower grain moisture contents, from 12 to 15% (w.b.), however, having one aerated silo is more economical compared with having 4 aerated silos due to lower ownership and operational costs. At this moisture content, the available dryer capacity is sufficient to dry the harvested grain before its quality degrades. From 16-22% moisture contents (w.b.), return is decreasing regardless of the number of aerated silos

used because at these range of moisture contents, grain is too wet and the aeration system is unable to treat it. At this moisture content and above, having a dryer is critically important.

CONCLUSION

The simulation model has shown that at the crop area of 600 ha, the maximum return will be obtained if grain is harvested at 16% moisture content (w.b.). It has also been shown that the investment in aerated storage with 145 tonne capacity will increase grain growers' income by 2% or \$6.5 if the grain is harvested between 15 and 22% moisture contents (w.b.). Having several aerated storage is also more economical than having only one aerated storage if grain is to be harvested at higher moisture contents. Grain grower's income will increase by 2% when each additional aerated storages is added. At lower grain moisture contents (12 to 15%), however, having one aerated silo is more economical compared with having 4 aerated silos due to lower ownership and operational costs.

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