ALTERNATIVES TO OPEN-FIELD BURNING ON PADDY FARMS

Malaysia has long been a major importer of rice however it has continued to satisfy the bulk of its demand through domestic production and this behavior is not expected to change anytime soon. Not only are millions of tonnes of rice grown each year in Malaysia but also millions of tonnes of the crop residue, which is better known as rice straw and makes up around 50% of the entire crop (Barreveld, 1989). This means that the amount of rice straw grown each year is roughly equal to the amount of rice paddy production. In 2010, paddy production in Malaysia was just over 2.5 million tonnes (FAOSTAT) meaning that around the same volume of rice straw was produced in that year. Considering a typical Malaysian paddy farm in 2007 which had 2.5 hectares[1] of paddy area and had an average annual yield of 3.5 tonnes of paddy rice per hectare[2], it produced around 8.75 tonnes of rice straw for that year.

Traditionally, rice straw was seen as a versatile by-product of rice cultivation as it was used in many ways including fodder for livestock and even as a building material. However, the increase in productivity and size of paddy areas, among other things, has led to a huge excess of rice straw where the most cost-effective way of disposing of the residue is seen as burning the biomass in the paddy field. Open-field burning is certainly a controversial topic and requires a thorough understanding of its effects. However, so do the potential effects of alternative rice straw management methods such as soil incorporation and the complete removal of the straw from the field.

Burning Rice Straw

Open-field burning is a widely practiced method all over the world; however, its intensity varies. For instance, Gadde, Menke, Wassman (2009) estimated that less than a quarter of rice straw is most probably burnt in India compared to around half in Thailand whereas almost all of the residue is burnt in the Philippines. The existence of traditional activities such as using rice straw as fodder for livestock and compost for other crops in countries like India may explain why open-field burning is less intensive there. Meanwhile in countries which have adopted newer forms of farming practices, such as replacing animal power with tractors like Thailand and China, may explain the increased tendency of burning rice straw in these countries. Malaysia certainly fits the latter group of countries where mechanized paddy farming now dominates. From the farmers' point of view, burning may be seen as the most suitable method of disposing of rice straw. It is not only a cost-effective method but it acts as an effective pest control procedure (Kadam, Forrest and Jacobson, 2000; Dobermann and Fairhurst, 2002). It is also seen as a way of preparing the soil for the next crop as well as releasing nutrients contained in the residue for the next crop cycle (Gadde, *et* al, 2009). What is more, the short-term effects from burning may seem even more desirable than those from soil incorporation due to the immobilization of inorganic nitrogen which occurs in the latter and can adversely affect productivity in the short-term (Singh and Singh, 2001).

As well as having numerous advantages, its critics highlight the many negative aspects of open-field burning. Perhaps the issue which has received most attention in recent years is the

[1] The median size of paddy farms in Malaysian granaries was roughly 2.5 hectares according to the collected data of the study by Amin *et al* (2009) which interviewed almost 500 paddy farmers.
[2] According to FAOSTAT, in 2007 the average annual yield of Malaysian paddy rice production was just over 3.5 tonnes per hectare.

atmospheric pollution created during the burning phase. Gadde, Menke, Wassman (2009) estimated that the burning of rice straw contributed 0.05%, 0.18%, and 0.56% of the total amount of greenhouse gas emissions in India, Thailand and the Philippines, respectively. The air pollutants are also a hazard to people's health (Kadam, Forrest and Jacobson, 2000; Gadde, *et* al, 2009; Cheewaphongphang, *et al*, 2011) particularly to those within local proximity to paddy areas. The event which brought rice straw burning to front page news in Malaysia was the car accidents the smoke from the straw caused on highways which were situated close to paddy areas (Malaysian Society of Social Science, 2004).

The less common arguments against the practice of open-field burning are related to the effect the practice has on the availability future crops have to nutrients. Singh and Singh (2001) noted that burning causes a loss of nutrients and organic matter. Not only is rice straw the major organic material available to rice farmers but a considerable amount of the macro-nutrients, namely nitrogen, phosphorus and potassium as well as important micro-nutrients like sulfur and silicon are contained in the rice straw (Dobermann and Fairhurst, 2002). However, assuming the rice straw is burnt rapidly *in situ*, according to Dobermann and Fairhurst (2002) the only major loss of nutrient content is nitrogen while the losses of the other nutrients are expected to be small. The aforementioned authors estimated that a tonne of rice straw contained 5-8kg of nitrogen. This would mean that the typical Malaysian paddy farm which produces 8.75 tonnes of rice straw each year and burns its entire residue would, in theory, lose between 43.75kg and 70kg of its soil's nitrogen stock each year due to burning. To put its magnitude into some kind of perspective, each year the typical Malaysian paddy farmer who has 2.5 hectares of paddy area receives the equivalence of 152kg of nitrogen from the government in the form of urea and NPK mix fertilizers[3]. Therefore one may say that between 48% and 76% of the urea[4] subsidy from the government goes towards replenishing the lost nitrogen from the burning practices. Interestingly, a tentative cost can be calculated as to measuring at least part of the cost of burning rice straw. In 2008, the total cost of the urea subsidies to paddy farmers was RM 72.5 million (Amin *et al*, 2009). If we make the assumption that the subsidized paddy farmers burnt their entire stock of rice straw then the cost in terms of the nitrogen losses was between RM 35 million and RM 55 million for that year which was paid for by the state.

In reality, the short-term costs of nutrient losses due to rice straw burning are dwarfed by the cost burning has on the condition of the soil and therefore future rice productivity. It has been found that continuous burning of straw leads to a reduction of nitrogen and carbon as well as soil aggregation (Malhi and Kutcher, 2007). It can also lead to water runoff and soil erosion (Biederbeck *et al*, 1980). In wheat cultivation for instance burning the residues in the field has been found to reduce productivity (Dormaar, Pittman and Spratt, 1979).

[3] Malaysian paddy farmers within granary areas who have less than 10 hectares of paddy area receive 10 bags of Sebatian (NPK mix) and 4 bags of urea per hectare every year for free from the government. The bags weigh 20kg each (Amin *et al*, 2009). Urea contains 46% nitrogen and I assume that blue NPK (12-12-17) mix is distributed.

[4] A paddy farmer with 2.5 hectares would gain 10 bags of urea which equates to 92kg of nitrogen. 43.75kg and 70kg are 48% and 76% of 92kg respectively.

Alternatives to Open-Field Burning

Incorporating the straw back into the soil is an alternative to burning, albeit an unpopular one with farmers. Its advantage is that it builds up organic matter in the soil as well as returning the nutrients contained in the straw back to the soil (Singh, 2001). However, it has been shown that the incorporation of straw contributes to significant levels of methane which enter the atmosphere and therefore contributes to greenhouse gas emissions (Wu *et* al, 2012). Reasons for its unattractiveness, some of which have been mentioned already, are that the straw can obstruct the seeding phase of the next crop and can also lead to reduced productivity in the short-term due to nitrogen immobilization (Singh and Singh, 2001; Malhi and Kutcher, 2007). For farmers with a short time-horizon such adverse effects may seem unacceptable.

Another alternative which has received much attention in the literature is the removal of the straw from the field and its use for other economic activities. Common suggestions include using straw rice to produce energy (Gadde, Menke, and Wassman, 2009; Delivand *et al*, 2011; Lim *et al*, 2012), and using it as a commercial feedstock for cattle (Kadam, Forrest, and Jacobson, 2000). These suggestions come with their caveats. In most cases, these grand ideas are hindered by the problem of financing such ventures. In most cases it would not be cost-effective for the straw to be transported too far away from the paddy farm. It would simply make the activities unprofitable which would not survive without continuous state funding. Another problem is that these activities are likely to be an even bigger contributor to greenhouse gas emissions. For instance, while Gadde, Menke, and Wassman (2009) found that burning rice straw contributed to 0.05%, 0.18%, and 0.56% of India, Thailand and the Philippines' overall greenhouse gas emissions, they estimated that generating electricity from the straw instead of burning it in the field would increase rice straw's contribution to 0.75%, 1.81%, and 4.31% in the respective countries' overall greenhouse gas emissions. However, the major drawback of these plus any other suggestions which require the complete removal of the straw from the paddy field is that the soil would lose all organic material and nutrient content from the straw which could be argued is even worse than open-field burning at least in terms of productivity and the sustainability of the soil.

There have been some other suggestions for alternatives of open-field burning which while include the initial removal of the straw advocate the return of the straw to the soil. Kausar *et al* (2010) suggest transforming rice straw into compost which can then be returned to the soil. Another suggestion which has already been put to practice in countries including the Philippines is the conversion of the rice straw into biochar which is then returned to the soil.

Biochar like charcoal is produced through burning organic materials like rice straw with no or extremely low levels of oxygen. However, the purpose of producing biochar is not so it will be burnt at a later period but is instead will be applied to soil in order to improve soil productivity (Lehmann and Joseph, 2009). When rice straw is burnt in the open it is exposed to plenty of oxygen therefore the combination of the carbon from the biomass and the oxygen in the air releases carbon dioxide into the atmosphere. The absence of oxygen during the burning phase means that the carbon in the biomass largely remains intact. The creation of biochar rather than ash therefore reduces the amount of greenhouse gases released into the atmosphere and it is believed that the carbon can remain in the soil for hundreds of thousands of years (Wu *et al*, 2012). Another advantage of biochar is its large surface area and pore volumes (Wu *et al*, 2011). This implies that biochar helps the soil retain nutrients and water which prevents leaching and therefore fewer inputs are wasted. Another benefit is that biochar has the capacity to adsorb[5] pollutants like pesticides before they enter local water sources (Takagi and Yoshida, 2003).

The current challenges facing the incorporation of biochar into the soil are that further research testing its impact on soil fertility is needed (Wu *et al*, 2012). Secondly, it creates extra work for the farmer which although there exist relatively simple methods of producing biochar on-site, there is an additional labor cost as compared to open-field burning. Solutions are being found, for instance the Philippine Biochar Association searches for domestic businesses who are willing to pay a fee which is paid to paddy farmers who convert their rice straw into biochar and incorporate it back into their soil. The Philippine Biochar Assocition then provides the customer with a certificate which they can use to show they have off-set their own carbon footprint through paying the farmer to capture the carbon which would otherwise have been released into the atmosphere.

It is important to recognize that while consistent open-field burning is not a sustainable practice it should still be seen as an option in cases of a pest or disease outbreak. For instance, even in Californian where there are strict burning regulations in place, with the permission of the local authorities farmers may burn a proportion of their rice straw in order to control pest infiltrations. It is clear however that an alternative to open-field burning needs to become the standard procedure and biochar incorporated into the soil is a method which appears to have promising potential not only in Malaysia but worldwide and therefore requires further research exploration.

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[5] Biochar adsorbs rather than absorbs substances. This means that substances collect along the surface of the biochar rather than being absorbed into the biochar itself.

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