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Abstract:
The irrigated rice-wheat cropping system is the predominant and most profitable farming system in north-west India, especially in Punjab. However, there are growing concerns about the environmental effects of the system, particularly with the practice of burning rice stubbles, due to its adverse effects on human health and air pollution. In this paper we consider the wide array of policy settings that tend to favour current land uses and management practices and their impact on the farming system over time. As part of an ACIAR-funded project, we assess the significance of these policies with a view to considering what additional or alternative policies could be put in place to encourage the adoption of approaches or technologies directly concerned with reducing the practice of stubble burning. We conclude that many of these policy settings limit the gains from technology adoption and might be better addressed prior to considering policies aimed at specific technological solutions.

1. Introduction

The rice-wheat farming system is the most dominant and profitable farming system in the Indo-Gangetic Plain region of north-west India. This is particularly the case in Punjab where it accounts for more than 2.6 million hectares or 60% of the total net sown area (Singh *et al*. 2008). Rice-wheat rotation has been heavily supported by both national and provincial governments through a range of input subsidies (machinery, fertiliser, water, electricity and credit) (Davenport *et al*. 2009) and price support mechanisms (USDA 2004).

The majority of the rice in Punjab is mechanically harvested, leaving heavy loads (more 6 tonnes per hectare) of anchored straw and loose straw in windrows. With short timeframes between the harvesting of rice and sowing the proceeding wheat crop, farmers have managed high stubble loads through the practice of burning. At present more than 90 per cent of the 23 million tonnes of rice stubble produced annually in Punjab is burnt each year. Burning is less prevalent in other Indian states where yields are lower and rice crops are harvested manually, leaving lighter loads of 2-4 tonnes per hectare of stubble in the field. Consequently, farmers can cultivate and sow wheat conventionally, or direct drill wheat into the rice residue, without significant difficulty.

Although stubble burning is a rapid and relatively cheap option for farmers in Punjab, there are long-standing concerns about both the on and off-farm effects of the practice (Singh *et al*. 2008). Air pollution from stubble burning is a particular issue. In Punjab more than 60% of the population live in the rice growing areas and are exposed to air pollution due to burning of stubbles (Kumar and Kumar 2010). Fine particulate matter from stubble burning causes acute asthmatic and cardio vascular problems in elderly people and children and is also associated with lung disease. Stubble burning also contributes significantly to greenhouse gas emissions (Gujral *et al*. 2010) and the thick clouds of smoke engulf roads, causing an increase in the number of accidents and blocking or slowing down traffic.

Farmers and governments at all levels in India are sensitive to the ill-effects of rice stubble burning and are looking for alternatives that are both environmentally sustainable and economic (Kumar and Milham 2010). Some of these alternatives concern the collection and off-farm use of stubbles (e.g., stock feed, paper production, fuel source in furnaces and gasifiers), while others involve on-farm management of the stubble load (eg., stock feed, mulching, direct drill machines). The Australian Centre for International Agricultural

Research (ACIAR) has been supporting the development of sustainable alternatives to stubble burning principally through the development of a direct drilling machine known as the Happy Seeder. The Happy Seeder is a tractor-powered machine that cuts and lifts the rice straw, sows into the bare soil, and deposits the straw over the sown area as a mulch. The Happy Seeder thus combines stubble mulching and seed and fertiliser drilling into a single pass (Sidhu *et al*. 2007, 2008).

Although the use of Happy Seeder has on-farm economic benefits, its adoption has been much slower than desired. Part of this slower adoption may well be related to its significant capital cost and its limited period of use on typical small size holdings. Through ACIAR we are investigating policy options to encourage the adoption of alternative stubble management practices in the Punjab region (like the Happy Seeder) with the aim of reducing the incidence of stubble burning. In considering possible future policy options, it's important to gain an understanding of how existing policy settings have favoured the dominance of the rice-wheat system and, indirectly, the practice of burning rice stubbles. We use a representative farm model of the rice-wheat farming system in Punjab to gauge the importance of these settings and to then consider whether specific technology-based incentives are required or whether reform to broader policy settings might be more efficient.

The outline of the paper is as follows. The next section tracks some of the major changes in policy settings that have influenced agriculture in Punjab. Section 3 then describes how agriculture in Punjab changed in response to these settings and notes some of the positive and negative effects of changes. Section 4 outlines the ACIAR Happy Seeder project. Section 5 then describes the modelling approach used to quantify the effects of alternative policy settings on optimal farm plans in the Punjab region and outlines some preliminary findings. Conclusions drawn from this analysis are provided in Section 6. The implications of the results for future policies towards the practice of stubble burning are discussed in the final section.

2. Agricultural Policy in India

A key objective of the Indian independence movement was to put in place institutions and policies that (i) would eliminate recurrence of the famines that had occurred during the colonial period, and (ii) which would also ensure that basic foods were available to the whole population at affordable prices (Pursell *et al.* 2007). In order to achieve these objectives, the government intervened in foodgrain markets from the late 1940s. However, droughts in the 1960s led to a crisis in 1966, when India produced only 72 million tons of grain and import dependency more that doubled (USDA 2004).

In the same year there was a 30 per cent[1] devaluation of the rupee against the pound and the US dollar. This substantially increased the cost of imports, accentuating the difficulties for the populace (and hence the government) associated with a high level of import dependency. This reinforced the determination to become self-sufficient in food grains and other basic agricultural products (Pursell *et al*. 2007). After the 1966-67 food crisis and because of concern with rising dependence on imported grain, India advanced the policy initiative now termed the Green Revolution.

The Green Revolution focussed on increasing food production by substantially improving agricultural productivity. The program was started with US aid and was marked by the arrival of imported high-yielding varieties of rice and wheat, increased use of inputs such as chemical fertilisers, herbicides, insecticides and pesticides, and irrigation. Many of these inputs, including seeds and the electricity used for irrigation and other agricultural purposes, were subsidised (Anand 2010; Davenport *et al*. 2009). Adoption of the new varieties and production technologies was aided by programs to subsidise the purchase of farm machinery, to ensure farmers ready access to credit[2], and to support farm-gate prices for food grains and other major crops (eg., minimum support prices) (USDA 2004).

Overall, from the perspective of food production, consumer affordability and stabilisation of domestic food prices, the Green Revolution and associated policy interventions were (at least for some considerable time)[3] an outstanding success story, for example:

- Food grain output in Punjab increased from 3.16 million tonnes in 1960-61 to 25.31 million tonnes in 2006-07.
- "*During the 60 years since independence in 1947, progress in India's wheat and rice sectors – which supply the bulk of daily calorific food intake for a population that now*

[1] Nominally 57.5 per cent, but estimated to be around 30 per cent in real terms (Pursell *et al*. 2007).
[2] In Punjab, for example, farmers pay a lower interest rate and have easier collateral and ability to pay requirements than other borrowers (Dr's Sandhu and Sidhu, Punjab Department of Agriculture, pers. comm., September 2008).
[3] Observing recent concurrent food price inflation and farm poverty, Basu (2010) commented: '*In the name of helping the farmer and the consumer, and likely even with the earnest intention of doing so, we have ended up creating a foodgrains policy framework that has not got high marks on either account. Many of India's poor households do not get adequate, nutritious food and many of our farmers remain impoverished.*' (pp5-6)

exceeds 1 billion people – has made India self-reliant in its major food staples." (Jha *et al*. 2007)

- *"Between 1965 and 1988, domestic rice and wheat prices declined by 44 percent and 52 per cent in real terms… Sugar is another example… domestic sugar prices have been kept quite stable for long periods, and have steadily declined over time in real terms."* (Pursell *et al.* 2007)

3. Changes in Punjab agriculture

In the early 1960s, agriculture on the Indo-Gangetic Plain of north-west India, including in Punjab, was largely characterised by dryland production systems with very low levels of purchased inputs. While wheat was the major crop as it is today, there was only occasional opportunistic double-cropping, and production of coarse gains and pulses far exceeded rice. Fifty years later, however, the total area under cultivation has expanded enormously and high-input, rice-wheat double cropping has become the dominant farming system (see Table 1). To understand the fundamental change that has taken place over this period, in terms of the area under crop, the production system and the crop mix, it is necessary to understand the impact of the policy settings in which the agriculture sector has developed.

Table 1: Trends in Crop Area in Punjab

Crop	**Year**			
	1960-61	**1980-81**	**2000-01**	**2008-09**
	'000 ha	'000 ha	'000 ha	'000 ha
Rice	227	1,183	2,611	2,740
Wheat	1,400	2,812	3,408	3,530
Maize	327	382	165	150
Cotton	446	648	474	530
Pulses	903	341	61	40
Oil seeds	185	248	87	60
Sugarcane	133	71	121	80
Total	**3,621**	**5,685**	**6,927**	**7,870**

Source: Government of Punjab

The support programs implemented during the Green Revolution helped India become a surplus producer of a number of cereals. In the process, however, the Government of India institutionalised policies and programs which, despite appearing to have a broad base across the cropping sector, in reality strongly favoured wheat and rice (USDA 2004; 2009).[4] Punjab – a state with large areas suitable for growing rice and wheat and with both surface and groundwater resources and requisite irrigation and infrastructure facilities - was hence a major beneficiary of the Green Revolution.

Timeliness of field operations for both rice and wheat is a key element in fitting both crops in each year and achieving high yields (Singh *et al*. 2008). In Punjab, given ready access to water, fertiliser and new short duration varieties it became possible to grow a high yielding rice crop (June-July to October-November) followed by a high yielding wheat crop (November-December to March-April). This allowed the introduction of a rice-wheat double crop rotation in areas that formerly could produce only rice or wheat in a single year. And, in addition to double-cropping, rice is now also grown on light to medium texture soils which were traditionally growing maize, pulses and oilseeds.

The advent of mechanical harvesting (supported by purchase subsidies and cheap access to credit) assisted this process by substantially reducing the duration of the rice harvest, thereby reducing both the risk of a rice crop failure and the risk that the relatively short planting window for wheat would be missed. Risk was also reduced by minimum support price (MSP) programs. While the MSP programs cover a large number of crops, only rice and wheat are backed up by government procurement arrangements which effectively guarantee prices for these commodities (USDA 2004)[5]. While the MSPs for rice and wheat have tapered down in recent years, they have traditionally been well above the cost of production in Punjab, particularly for rice (Figure 1) (Pursell *et al.* 2007).

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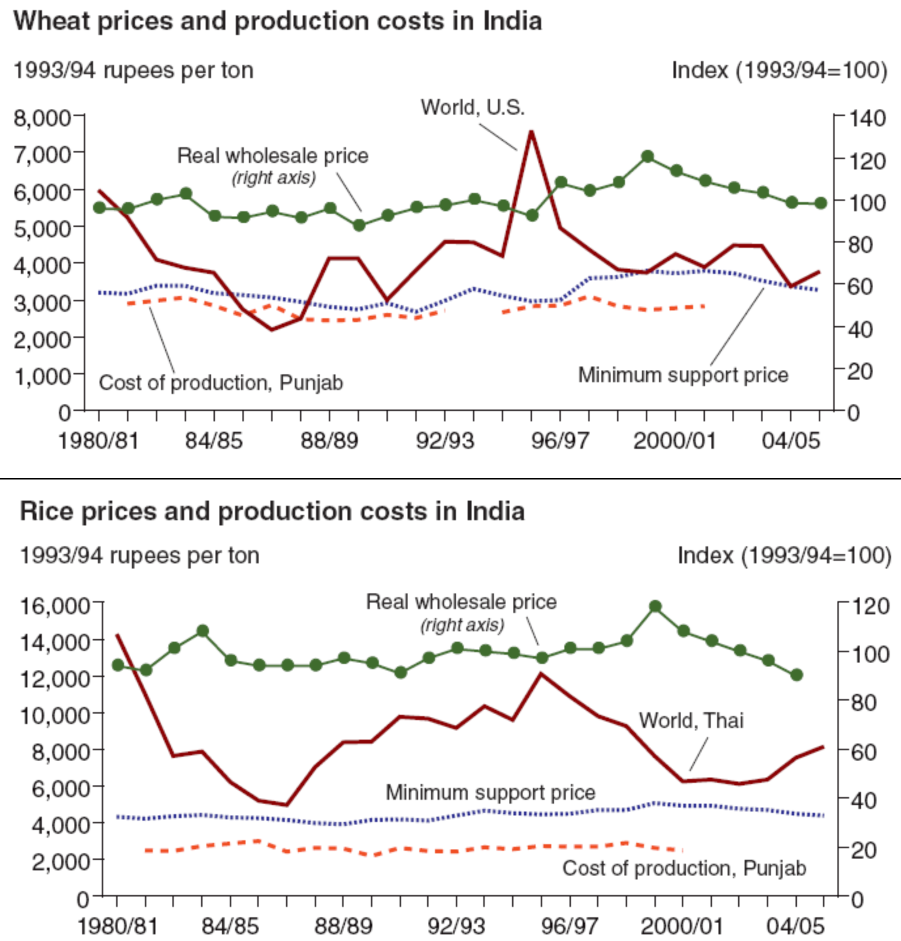
[4] For example, paddy and wheat growers consume 35 per cent and 19.3 per cent of total fertilizers, respectively. Paddy and wheat use 79.7 kilograms (kg) and 85.32 kg of fertilizer per hectare, whereas coarse cereals and other crops use 28.8 kg and 42 kg per hectare, respectively" (Fan et al. 2004).

[5] Each year, the Food Corporation of India purchases roughly 15-20% of India's wheat production and 12-15% of its rice production (Food Corporation of India 2010).

Figure 1: Wheat and Rice Prices and Production Costs

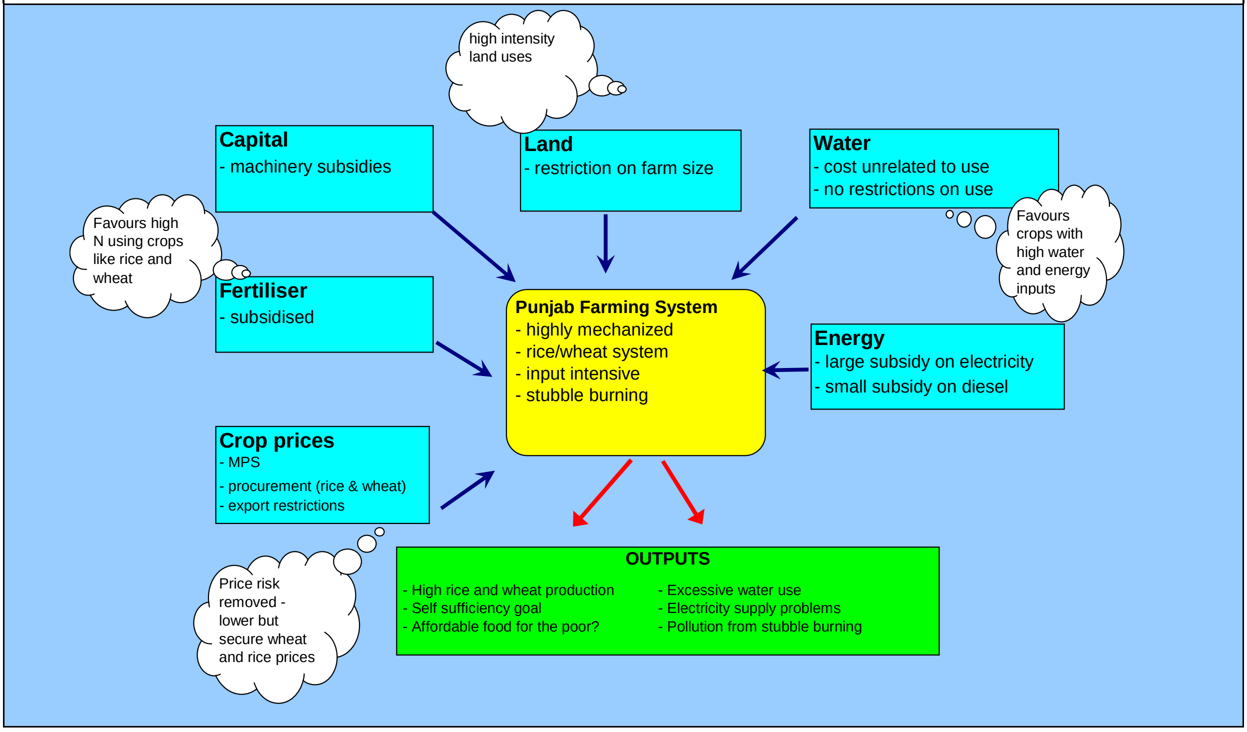


Source: Pursell *et al.* (2007)

As illustrated in Table 1, the overall response to the incentives created through government interventions (summarised in Figure 2) and the yield advantages of the new varieties of rice and wheat over others under irrigation, has been to induce farmers to expand cultivation and shift their production to these crops from coarse cereals, pulses and even oilseeds, especially in Punjab and Haryana (PTI 2004). In Punjab, agriculture has to in large part transitioned into a rice-wheat double cropping production system. Continuous rice-wheat rotation has expanded to now be more than 2.6 million hectares or 60 per cent of the total sown area in Punjab (Singh *et al.* 2008): about 90-95 per cent of the rice area is under the intensive rice-wheat system (Gadde *et al*. 2009).

In summary, the farming system on the Indo-Gangetic Plain in north-west India is predominantly mechanised, irrigated, continuous rice-wheat rotation because of the combined influences of:

Figure 2: Influence of Government Programs on Farming in Punjab



- the natural assets of the Plain (topography, soils, climate and irrigation water); and
- government intervention (input subsidies, trade restrictions and commodity price support).

While food production, consumer affordability and domestic food price stabilisation objectives have largely been met, it is now becoming apparent that these benefits have come at some environmental and social cost and there are strong concerns over the sustainability of the farming system. The system is considered to be very important to Indian food security, but:

- productivity is low by world standards (USDA 2004);
- water consumption is high and groundwater supplies are being depleted (Department of Agriculture and Cooperation 2009);
- soil fertility is declining and fertiliser rates are excessive and rising (Anand 2010);
- energy (electricity and diesel) demand is high;[6]
- at least in Punjab, rice stubble is largely burned in the field, giving rise to air pollution and negative on-farm productivity consequences; and

[6] According to Jha et al. (2007), the cost of providing free or subsidized (depending on the State) electricity for agriculture accounts for more than two-thirds of total input subsidies. Furthermore, the agriculture sector consumes 29% of power generated, but contributes only 3.36% of electricity sales revenue (Fan *et al.* 2007).

- the subsidy programs are very costly to government.[7]

The practice of rice stubble burning is the particular focus of this paper. Due to the heavy stubble loads generated by high yielding rice varieties, time pressure between the rice harvest and wheat planting, rising labour costs and subsidies that have promoted mechanisation, management practice has shifted away from hand harvesting to combine harvesting. This process leaves high volumes of anchored stubble in the field, for which a management solution must then be found. The residues of high yielding rice varieties have high silica content and are of little value on-farm for stockfeed, particularly in a system that also produces wheat straw.

While stubble is a partial alternative to fertiliser in preparing the soil for planting, with the availability of cheap (subsidised) fertiliser the more costly options of stubble incorporation or application as mulch are unattractive to farmers. Also, late harvesting of rice results in late planting of wheat and may cause significant yield penalties. As tillage to incorporate rice residues is time consuming and exacerbates the risk of late wheat planting, farmers have to a large extent resorted to burning off rice residues prior to planting wheat (Figure 3).

Figure 3: Burning Rice Stubble Prior to Sowing Wheat in Punjab

4. The ACIAR 'Happy Seeder' Project

The Happy Seeder technology (Figure 4) has been developed India and is designed for direct drilling wheat into heavy rice residue loads on smallholdings and therefore provides an alternative to stubble burning. It is a tractor-powered machine that cuts and lifts the rice straw,

[7] The total cost was estimated at US$11.9 billion in 2005/06, accounting for about 15% of total government expenditure in that year (Jha *et al.* 2007).

sows into the bare soil, and deposits the straw over the sown area as a mulch. It combines the stubble mulching and seed and fertiliser drilling operations into one machine in a single pass (Sidhu *et al*. 2007, 2008). Field trials indicate that it offers on-farm benefits through higher crop yields, increased cropping opportunities, less weed growth, improved soil quality and structure and lower water consumption – an important feature given concerns about declining water supplies in north-west India (Singh *et al*. 2008).

As part of the research to develop the machine, a simple preliminary financial analysis was undertaken which suggested that investment by farmers in the Happy Seeder technology would be financially viable (Singh *et al*. 2008). The Happy Seeder therefore appears to have considerable promise to provide environmental and community benefits as an alternative to burning as a means of managing rice residues.

Figure 4: The Happy Seeder Direct Drilling Wheat in Standing Rice Stubble

Despite the identified on- and off-farm benefits and government assistance, to date there has been only a relatively low level of adoption of the Happy Seeder. ACIAR therefore commissioned an investigation into potential incentives to increase adoption of the technology. CSE/2006/132 *Policy instruments to address air pollution issues in agriculture -*

Implications for Happy Seeder technology adoption in India was undertaken by the NSW Department of Industry and Investment in Australia (I&I NSW) in partnership with ACIAR and the National Council of Applied Economic Research (NCAER) in India.

The project has focused on the effectiveness and desirability of increasing government subsidies for the purchase of Happy Seeder machines in the combine harvested, rice-wheat farming system of north-west India. To properly address this issue it is necessary to give consideration to the private incentives (and disincentives) for adoption of the Happy Seeder, which depend upon the production economics of the technology; policy and market signals relating to enterprise selection and input management; and government policy in relation to prevention of pollution.

In addition, it should be appreciated that introduction of technology like the Happy Seeder is only one of an array of potential options to reduce the practice of stubble burning. These range from the provision of information to farmers on alternative strategies that could be adopted, to changing incentives to stimulate change to the farming system (i.e., encouraging a shift to production systems that produce less anchored stubble and/or consume more of the stubble produced) to directly restricting or taxing air pollution or greenhouse gas emissions.

5. Testing Policy Alternatives

The preceding sections of the paper have outlined the wide array of policy settings that tend to favour current land uses and management practices and their impact on the farming system in Punjab over time. In this section we assess the significance of these policies with a view to considering what additional or alternative policies could be put in place to encourage the adoption of approaches or technologies, such as the Happy Seeder, that would reduce the practice of stubble burning.

5.1 Farm level model of Punjab agriculture

5.1 Overview

To assess the influence of policy settings on land use and technology adoption in Punjab we developed a farm level model of agriculture in Punjab. The model attempts to represent the key physical and economic characteristics of small-scale farming in Punjab. The farm level model is of a linear programming (LP) form and adheres to the general farm planning maximisation problem, where an objective function is maximised through the choice of an optimal set of activities, subject to a number of physical constraints. LP has been extensively applied to a wide range of agricultural issues and is one of the most widely used optimisation techniques.[8]

Linear programming was considered to have particular advantages in this study. There are many ways in which policy settings in India can influence land use, various options for policy change and many complexities associated with the double cropping farming system adopted in Punjab. Under these conditions it is difficult to fully consider the possible interactions between various policy settings and land use in the absence of a formal model. A significant constraint on the adoption of alternative investigation methods was the limited availability of empirical data, owing to the fact that many of the potential policy settings have never been implemented.

The Punjab farm level LP model is set up as a standard farm planning maximisation problem of the following form:

$$\text{Max} \quad Y = \sum_{j=1}^{n} c_j x_j \tag{1}$$

Subject to:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad (i = 1 \text{ to } m) \tag{2}$$

and:

$$x_j \geq 0 \qquad (j = 1 \text{ to n}) \tag{3}$$

where Y is the objective function to be maximised, c_j are the objective function values for the decision variables, x_j are the decision variables, a_{ij} are the input-output coefficients and b_i are the resource constraints. In a typical farm planning problem, the objective is to find the farm plan (represented by decision variables x_j) that leads to the highest level of net farm income Y, but which does not exceed the fixed resources of the farm or permit negative activity levels (Hazell and Norton 1986). Each of these elements is now described in the context of the representative farm model of Punjab agriculture.

[8] A well formulated LP model offers a number of advantages over more simplified spreadsheet-based analyses. There are also, however, a range of well-documented deficiencies of LP methods (see Hardaker 1971; Dent *et al.* 1986) including an assumption of linearity, perfect divisibility and an objective function which maximises profit (in this case) where other objectives might also be equally applicable. Dent *et al.* (1986), Pannell (1997) and others suggest that many of these problems can be minimised with a little thought and ingenuity.

The objective function of the Punjab LP model assumes that the farmer's aim is to maximise net farm income (Y) by selecting the optimal mix of crop and livestock activities (x_j) subject to constraints on land, labour, capital and water (b_i). Policy settings associated with inputs of electricity, water, fertiliser and machinery (including the Happy Seeder technology) were introduced either through changes in the objective function values (c_j) or by changes to resource constraints (b_i). Policy settings concerning the pricing of outputs (e.g. minimum support payments for rice and wheat) were also reflected directly in the assumed objective function values.

There are approximately 250 activities (x_j) represented in the model. These are comprised of: alternative crop activities (rice, wheat, maize, soybean, mungbeans) under different water application rates (low, average, high), irrigation layouts (flood irrigated and raised beds) and establishment methods (conventional, direct seeding, Happy Seeder technology for wheat); pasture activities (summer, winter and opportunity pasture); and livestock activities (cows, buffaloes and bullocks). Separate annual activities were introduced to cover the sale of grain and alternative uses of stubble (on-farm livestock use, sale, burn) and the purchase or hire of some inputs (nitrogen fertiliser, permanent labour, machinery). Monthly activities were also included to cater for within-season labour, irrigation water demands, pasture and fodder transfers and purchases, and on-farm milk production and household consumption.

The model parameters were specified to reflect a typical rice-wheat farm in Punjab (Table 2). The farm draws water from groundwater supplies in order to irrigate predominantly rice and wheat crops grown in rotation. The central and state governments provide free electricity to farms for this purpose. However, the high demand placed on electricity supply at key times results in power outages and restrictions in access to the otherwise free electricity. At these times, farmers revert to the use of their much more expensive diesel pumps. Although the model includes constraints on monthly water availability, these constraints are set to non-binding levels to reflect the current situation of unmetered access. Access to water is assumed to be only limited by pump size, although there has been a long term downward trend in groundwater levels in the region which may necessitate some form of restriction in the future. No prices are placed on the water resource itself so the marginal cost of using water from a farmer's perspective relates directly to the operating costs of pumps. A major component of this cost relates to energy use, which in the case of electricity is provided free of charge.

The main focus of the modelling was to understand the importance of policy settings in influencing land use, the use of inputs and the adoption of new technologies. With this in mind, some of the key inputs required for cropping activities (eg., water, electricity, fertiliser) were identified separately to facilitate an assessment of changes to policy settings. Base information on the input-output coefficients (grain and stubble yields, irrigation requirements, rotational effects associated with weeds, disease and nitrogen status etc) associated with each cropping activity were based on Dhaliwal *et al.* (2006) and Singh *et al.* (2006). Input prices and output prices were based on 2005-06 data. These input costs and market prices reflect current policy settings which provide significant subsidies on electricity, water, fertiliser and machinery inputs, whilst also guaranteeing prices for rice and wheat through the government's procurement program. Parameters concerned with the specification of the Happy Seeder technology were based on Singh *et al.* (2010).

Table 2: Punjab representative farm model parameters

Attribute	**Value**
Farm Area	4.40ha
Crop Area	4.20ha
Cropping Season	Summer, Winter
Crop and livestock activities	rice, wheat, mungbeans, maize, soybeans
Water source	groundwater only (unrestricted access and unpriced)
Irrigation infrastructure	7.5HP electrical pump, 5HP diesel pump
Electricity access	Jun-Jul - 5hrs/day, Apr-Aug - 6hrs/day, Remainder - 8hrs/day
Labour	Owner/operator, family, 1 permanent, casual

5.2 Findings

As described above, the modelling approach used exposed the representative farm model to selected alternative policy settings to examine the subsequent response in the optimal farm plan and resultant outcomes for key variable such as landuse (i.e., the area under various crops), adoption of the Happy Seeder, net farm income and water use.

The policy settings varied for the purposes of this paper related to fertiliser and electricity prices. While electricity is currently free for farmers in Punjab, a search of the literature (eg., Fan *et al*. 2007) suggested that if Indian farmers paid the same cost for electricity as other industrial consumers then this would equate to a price of around 3.60 rupees per kilowatt hour. This value was used as a reasonable estimate of an unsubsidised electricity price that farmers in Punjab might be expected to pay. Similarly, a crude estimate of the on-farm benefit of the subsidies provided to fertiliser manufacturers (calculated by dividing the total subsidy paid to the Indian fertiliser industry in 2008/09 by the tonnage produced in the same year and assuming that the subsidy is fully passed to farmers) is about 2.14 rupees per kilogram of Nitrogen. The 'without subsidies' scenarios therefore involved adding this margin to the cost of fertiliser, and costing electricity at 3.60 rupees per kilowatt hour.

The model is optimised under these alternative policy settings, first with the set of enterprise options constrained to those most commonly observed on farms in Punjab (wheat, rice and maize), and second, with the option of mungbean as a third crop in the rotation.[9] Results for the constrained crop mix scenarios are presented in Figures 5-7. Results for the 3-crop rotation option are presented in Figures 8-10.[10]

Under the current subsidy regime, the optimal farm plan had the following characteristics:

- most of the productive area of the farm (4.20 hectares) is under a rice (3.9 hectares) - wheat (4.2 hectares) rotation;
- there is a very small area of maize production (0.2 hectares);
- net farm income is about 153,000 rupees per year;
- the farm consumes around 81.4 megalitres of water per year; and
- the management system does not include use of a Happy Seeder so all rice stubbles are burned.

When production costs are adjusted to remove the effects of the subsidies on electricity and fertiliser, the following model responses are observed:

- rice, which is a comparatively high consumer of water and fertiliser, becomes less profitable and the area under this crop drops by more than 40 per cent to 2.3 hectares, with maize taking up the area no longer planted to rice;
- the total area under wheat remains at 4.2 hectares;
- the savings in irrigation and fertiliser usage associated with stubble retention make the Happy Seeder an attractive option and all of the rice area is planted to wheat using this technology;

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[9] A significant additional benefit of direct drill technologies, such as the Happy Seeder, is time savings that create the potential for a further short-duration crop to be grown.

[10] Final checks on the model are still being conducted, so while the authors have reasonable confidence in them these results should be considered to be indicative, rather than final.

Figure 5: Optimum Farm Plan With and Without Current Subsidies

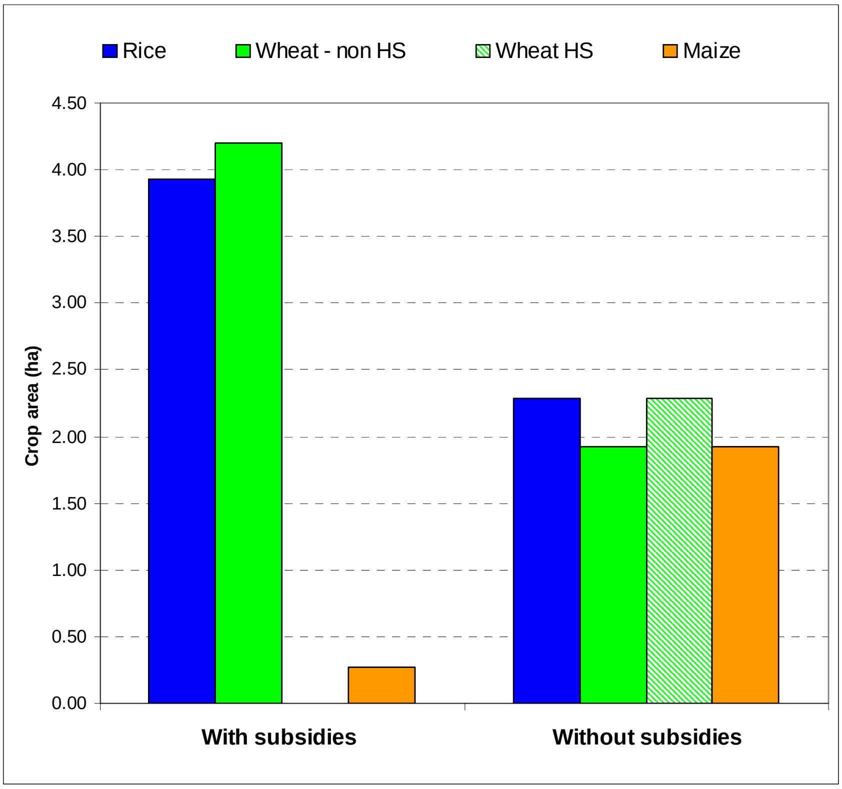


Figure 6: Net Farm Income With and Without Current Subsidies

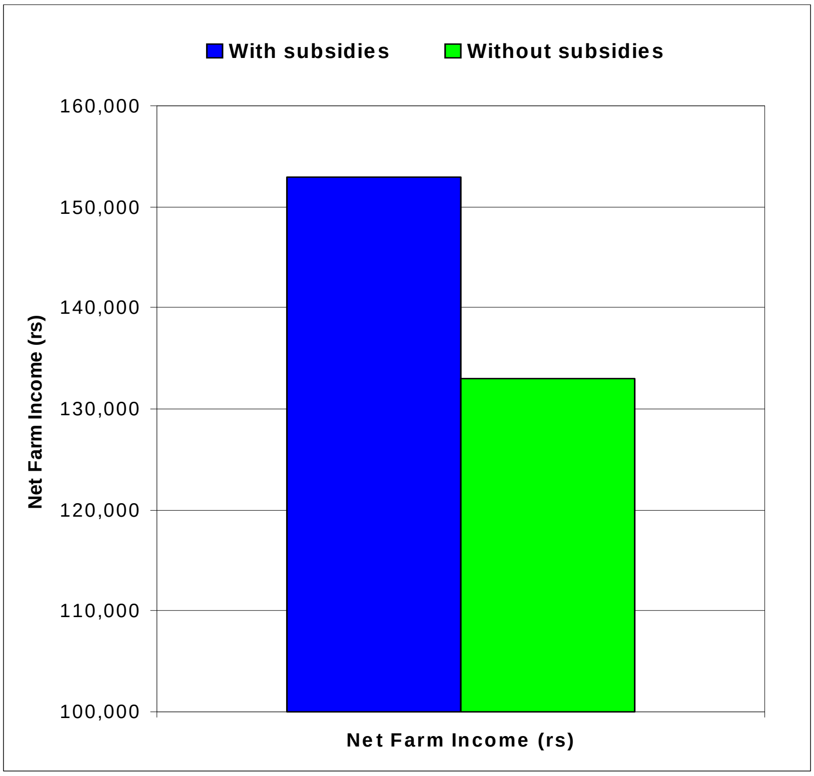
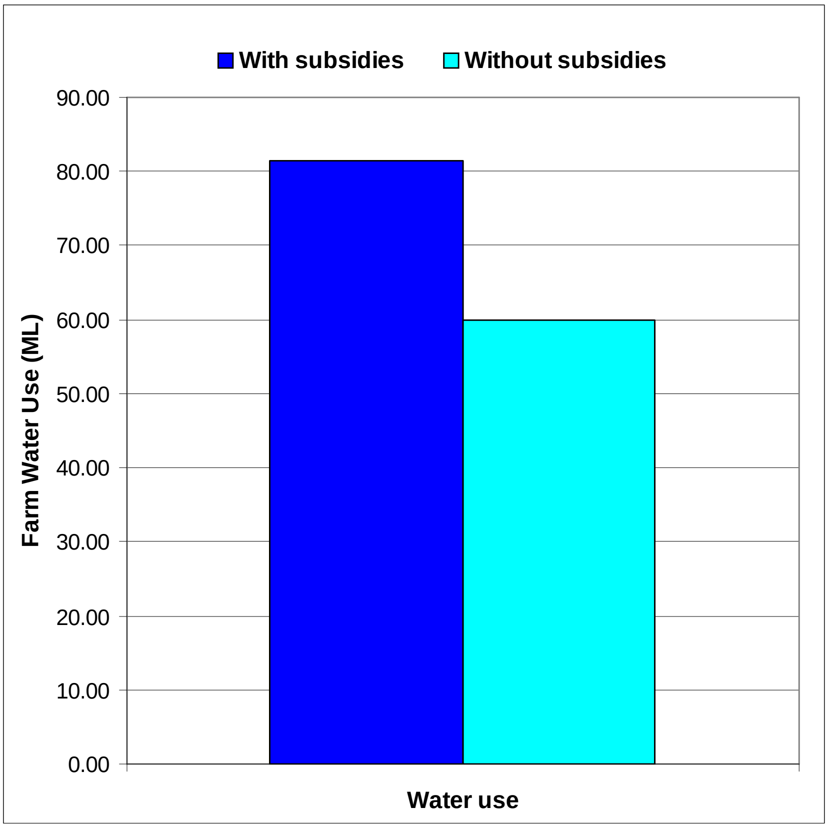


Figure 7: Water Use With and Without Current Subsidies



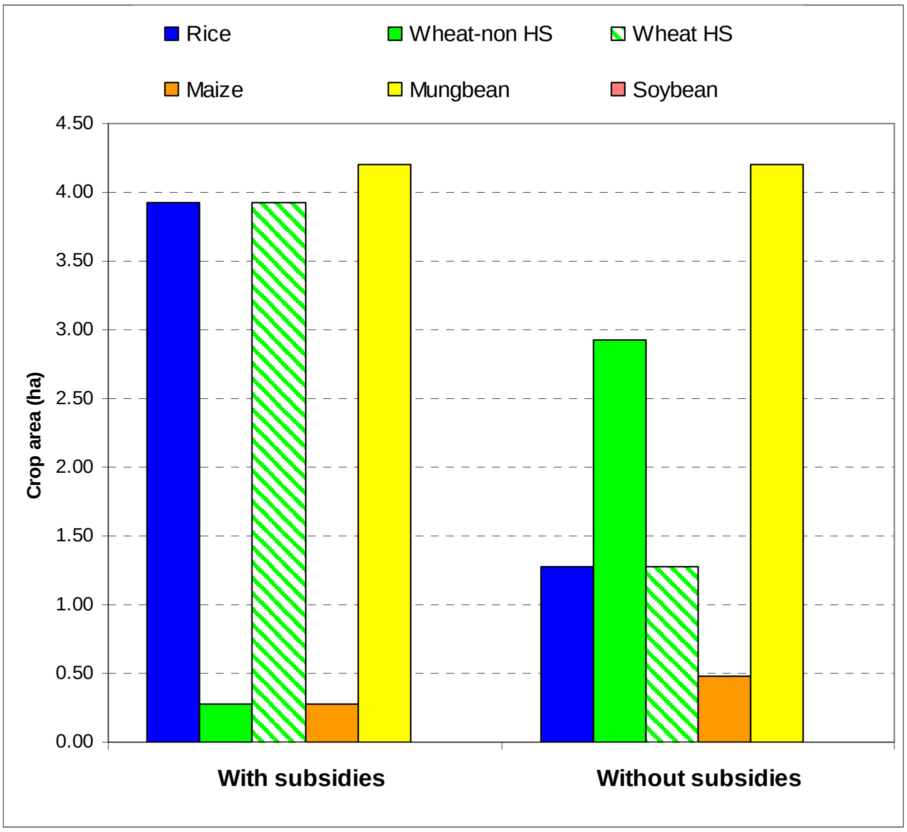
- despite losing the electricity and fertiliser subsidies, rice becoming less profitable and the cost of hiring a Happy Seeder, net farm income is reduced by only around 13 per cent (down to 133,000 rupees per year); and
- water consumption is reduced by more than a quarter, to 60 megalitres per year.

While it might seem from the above that it could also be concluded that rice stubble burning would cease under the 'without subsidies' scenario, other direct drill technology that still requires stubble burning is only marginally less profitable than using Happy Seeder. This technology could be easily substituted for the Happy Seeder and thus deliver similar on-farm outcomes without providing the additional public benefit of reduced stubble burning.

In the second set of results we examined potential changes in the farming system (beyond those crops widely practised) that might be triggered by policy settings which removed subsidies on electricity and fertiliser. The results reported in Figures 8-10 include the possibility of growing a third crop, namely mungbean, between the wheat and rice crops. This is found to substantially improve the economics of direct drill technology such as the Happy

Seeder over conventional farming[11] because it adds further income and provides rotational benefits through improvements in soil condition and the biological fixation of nitorgen. The key point to note from this latter analysis is that the optimum production mix, even with current subsidies, includes use of the Happy Seeder. That is, hiring a Happy Seeder is already privately profitable if it provides an opportunity for a third crop.

Figure 8: Optimum Farm Plan With and Without Current Subsidies With Three Crop Rotation Option



[11] It again should be noted that direct drilling wheat after burning rice stubble may also open up the option of a third crop, so this benefit is not unique to the Happy Seeder, however, only the Happy Seeder provides the additional benefit to the public of the rice stubbles not being burned.

Figure 9: Net Farm Income With and Without Current Subsidies With Three Crop Rotation Option

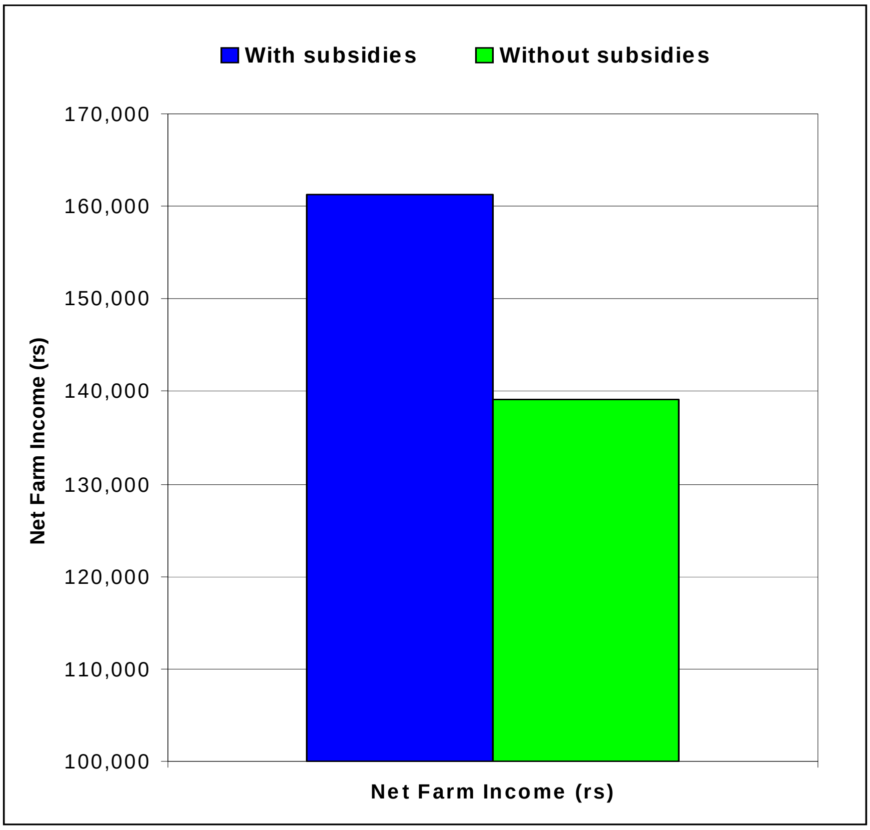
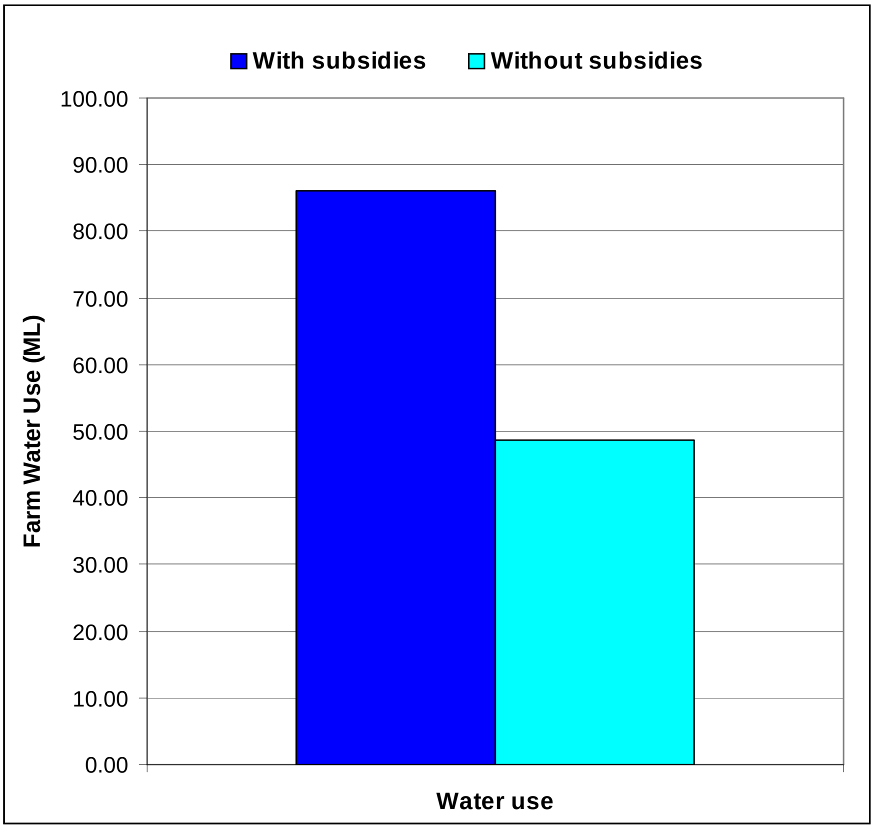


Figure 10: Water Use With and Without Current Subsidies With Three Crop Rotation Option



6. Conclusions

It is readily apparent that historical government policy settings have heavily influenced adjustment in the agriculture sector in Punjab. While these policies have to some extent delivered on objectives relating to expanded production of key food crops, such as rice and wheat, and price stabilisation for consumers, there are strong and increasing concerns about sustainability of the farming system they have spawned. Using representative farm modelling and focussing on the specific case of the Happy Seeder, we have demonstrated that many of these policy settings act to limit the gains from adoption of improved production technologies. The economic analysis clearly indicates the masking effects of electricity and fertiliser subsidies on the potential on-farm, environmental and public health benefits of the Happy Seeder technology.

While options such as enhancing the government subsidy on the Happy Seeder could be considered as a mechanism to encourage increased adoption, adjustment of these broader policy settings might be a better approach than support aimed at specific technological solutions. For example, exposure to unsubsidised market prices for electricity and fertiliser, while impacting to some extent on rice production, would increase the attractiveness of technology such as the Happy Seeder and likely encourage adjustment to a farming system that uses less electricity, less water and generates far less air pollution.

7. References

Anand, G. (2010), Green revolution in India wilts as subsidies backfire', *The Wall Street Journal*, 22 February.

Basu, K. (2010), *The Economics of Foodgrain Management in India*, Ministry of Finance working paper, Government of India, New Delhi, September.

Davenport, S., R. Chadha and R. Gale (2009), Competition Policy reform in agriculture: A comparison of the BRICs countries, Presented paper to the 53rd Annual Conference of the Australian Agricultural and Resource Economics Society, Cairns.

Dent, J.B., Harrison, S.R. and Woodford, K.B. (1986), *Farm Planning with Linear Programming: Concept and Practice*, Butterworths, Sydney.

Department of Agriculture and Cooperation (2009), National Agriculture Policy, http://www.nls.ac.in/CEERA/ceerafeb04/html/documents/agri.htm, Ministry of Agriculture, Government of India (accessed 29 October 2009).

Dhaliwal, H.S., Singh, R.P, Tejpal Singh, Yadvinder-Singh, Humphreys, E. and Kukal, S.S (2006). 'A financial analysis of permanent raised beds for rice–wheat and alternative cropping systems in Punjab, India'. In ACIAR Proceedings No. 127.

Fan, S., A. Gulati and S. Thorat (2007), *Investment, Subsidies, and Pro-Poor Growth in Rural India*, IFPRI Discussion Paper 007/16, September.

Food Corporation of India (2010), http://fciweb.nic.in/Region_information/punjab_region.htm

Gadde, B, S. Bonnet, C. Menke and S. Garivait (2009), 'Air pollutant emissions from rice straw open field burning in India, Thailand and the Philippines', *Environmental Pollution* 157, 1554-1558.

Gujral, J., S. Davenport and S. Jayasuriya (2010), 'Is there a role for agricultural offsets in sustainable infrastructure development: A preliminary assessment of issues', chapter 25 in *India Infrastructure Report 2010*, Oxford University Press, October.

Hardaker, J.B. (1971), *Farm Planning by Computer*, Technical Bulletin 19, Ministry of Agriculture, Fisheries and Food, London.

Jha, S., P.V. Srinivasan and M. Landes (2007), *Indian Wheat and Rice Sector Policies and the Implications of Reform*, Economic Research Report Number 41, Economic Research Service, USDA, May.

Kumar, P. and S. Kumar (2010), *Valuing the health effects of air pollution from agricultural residue burning*, Invited Paper to the ACIAR Workshop "Policy Options to Reduce Rice Stubble Burning", Punjab State Marketing (Mandi) Board, Chandigarh, 13-15 October.

Kumar, P. and N. Milham (2010), 'Policy instruments to address air pollution issues in agriculture', South Asia Newsletter, May, 18-19, ACIAR.

Landes, M. (2008), *The Environment for Agricultural and Agribusiness Investment in India*, Economic Information Bulletin No.37, Economic Research Service, USDA, July.

PTI (2004), MSP hike for grains, oilseeds, cereals, pulses, groundnuts, www.outlookindia.com, CCEA-MSP, New Delhi (accessed 10 August 2004).

Pannell, D.J (1997), Introduction to Practical Linear Programming. John Wiley & Sons, New York.

Pursell, G., A. Gulati and K. Gupta (2007), *Distortions to Agricultural Incentives in India*, Agricultural Distortions Working Paper 34, World Bank Development Research Group, December.

Sidhu H.S., Manpreet-Singh, J. Blackwell, E. Humphreys, V. Bector, Yadvinder-Singh, Malkeet-Singh and Sarbjit-Singh (2008), 'Development of the Happy Seeder for direct drilling into combine harvested rice', In *Permanent beds for rice-wheat cropping systems and direct drilling into rice residues*, E. Humphreys and C. Roth (ed's), ACIAR Proceedings No. 127.

Sidhu H.S., Manpreet-Singh, E. Humphreys, Yadvinder-Singh, Balwinder-Singh, S.S. Dhillon, J. Blackwell, V. Bector, Malkeet-Singh and Sarbjeet-Singh (2007), 'The Happy Seeder enables direct drilling of wheat into rice stubble', *Australian Journal of Experimental Agriculture* 47.

Singh, R.P, Dhaliwal, H.S, Tejpal-Singh, Sidhu, H.S, Manpreet-Singh, Yadvinder-Singh and Humphreys, E (2006). "A financial assessment of the Happy Seeder for rice–wheat systems in Punjab, India". In ACIAR Proceedings No. 127.

Singh, R.P., H.S. Dhaliwal, E. Humphreys, H.S. Sidhu, Manpreet-Singh, Yadvinder-Singh and J. Blackwell (2008), 'Economic assessment of the Happy Seeder for rice-wheat systems in Punjab, India', Contributed Paper to the 52nd Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra, 6-8 February.

USDA (2004), *Grain Report: India*, USDA Foreign Agricultural Service, Grain Report Number IN4089, 19 August.

USDA (2009), India: Policy, http://www.ers.usda.gov/Briefing/India/Policy.htm (accessed 27 October 2009).