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EVALUATING AGRICULTURAL POLICY IN A FARMING SYSTEM FRAMEWORK: A CASE STUDY FROM NORTH WEST INDIA

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Evaluating Agricultural Policy in a Farming System Framework: A Case Study from North West India

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Abstract

The present study evaluates effect of price, technology and institution-related policies of the Indian government on an average farm in North West India. The present evaluation assumes that with the rationalization of farm input and output prices farmers would adopt suitable technologies under a given institutional framework that will maximize Farmers objective function. A static linear programming-based model that maximizes profit and parameterizes risk has been chosen to present farmer's objective function. The model simulates alternate price, technology and institution-related scenarios on an average farm; these scenarios have been compared on the basis of several economic, ecological and social indicators that influence long term-growth of agriculture in the region. Findings suggest that price rationalization alone would not be sufficient for the long-term growth of agriculture in the region; technology and institutions play also an important role.

Introduction

Government intervenes in the agricultural market to achieve a particular set of policy objectives. Though short-run objectives of such policy interventions are achieved, the long-run implications of such interventions are at times not understood properly. As a consequence one set of policy objectives leads to certain consequences that were not thought of at the time of initiation of such policy interventions. Such a situation arises primarily because of an inadequate assessment of the externalities associated with the policy objectives. Some of these externalities are difficult to identify in the short run. At times these externalities interact amongst themselves to give a different net effect for the system; the net effect may not necessarily be negative.

Alternate policy options are often suggested to increase the long-term growth of agriculture as for example, rationalization of agricultural prices is often perceived as one of the most important policy options. There are also researchers who play down the role of price and highlight the role of institutions in promoting the long-term growth of agriculture. Extreme positions about price and institutions at times have resulted in a reversal of some of

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the government initiatives. This also introduces uncertainty into the system. The long-term implications of government policies therefore need to be assessed at the level of farm since it is the farmer, who responds to a policy intervention.

Incorporation of some of the above externalities in the decisional analysis is beset with several problems. In general there is a trade-off between economic objectives and the externalities associated with a policy objective; the complexities of interactions are often captured in the form of a system of equations. The system of equations differentiated on the basis of techniques involved, ranges from econometric modeling to input-output analysis and general equilibrium models. The technique involved in the model determines the amount and kind of data required for the model and also inferences from the model. The macro-econometric models, for instance, do not directly incorporate welfare and often concentrate on one measure of activity usually Gross National Product. The input-output based analysis provides detailed sectoral impacts; similar degree of dis-aggregation would in principle be available from general equilibrium (GE) models, but data requirements for the GE analysis are generally very high. Input-output analysis avoids this problem by imposing a set of strong restrictions on production technologies; it is however, difficult to optimize input-output models. The linear programming (LP) techniques have many essential features of an input-output analysis; and at the same time the LP technique is more amenable.

The present study attempts to assess the impact of alternate price and technology-related policies on various economic and ecological factors that influence the long-term growth of agriculture. Following rationalization, changes in the price of agricultural commodities would be significant (may be 10 per cent or 20 per cent); such changes can be captured in a linear programming framework in a better way[1]. Considering the relative merits of alternate techniques, the present study has used the linear programming model to evaluate the effect of changes in agricultural polices on a farming systems framework. The benign or malign effect of an intervention depends on the natural resource endowment of the region. The northwest region of India is chosen purposefully for the present evaluation as this region has been in the forefront of commercialized agriculture and farmers here can respond to policy changes in agriculture in a better way.

[1] General Equilibrium based model, unlike linear programming, studies the effect of policy changes on a variable with the elasticity coefficient. Elasticity generally refers to small changes of 1 to 3 percent (Source: Taylor and Naude 1999)

The present paper is divided into four parts as follows: the next section presents the analytical framework of the study. Section III on results and discussion illustrates various economic and ecological benefits and costs associated with specific technological options and it also discusses the results of the present evaluation. The last section draws conclusions from previous discussions.

II. Analytical Framework and Data

As explained above, a static linear programming model has been used to arrive at farm plans in an alternate scenario. The model maximizes profit and parameterizes negative deviation initially suggested by Hazell (1971) in a linear programming framework. Subsequently several researchers (Jha, 1995) have used the model to incorporate return and risk in a linear programming framework. The Linear Programming Model is specified as under:

Objective function:

Maximize

$$Z = \sum c_i X_i - \sum p_m L_m - \sum p_r P_w - \sum p_w C_w - \sum p_f F_n + \sum p_s R_s \qquad \text{- - - (1)}$$

Subject to following resource and non-resource constraints

Land restriction: $\sum a_{ij} X_i \leq LH$ - - - (2)

Water constraint: $\sum w_i X_i - P_w \leq CIW$ - - - (3)

Labour constraint: $\sum l_{im} X_i - L_m \leq FLM$ - - - (4)

Working Capital Constraints:

$$\sum k_i X_i + \sum p_r P_w + \sum p_m L_m + \sum p_w C_w + \sum p_f F_n + \sum p_p R_p - \sum p_s R_s - C_w \leq WC \qquad \text{- - -(5)}$$

Fertilizer nutrient (N, P, K) balance: $\sum f_{in} X_i - F_n = 0$ - - - (6)

Fodder (dry and green) balances: $- \sum s_i X_i + R_s = 0$ - - - (7)

Fuel balance: $- \sum f_i X_i = 0$ - - - (8)

Deviation as constraint in MOTAD: $\sum (c_{hi} - g_i) X_i + Y_h \geq 0$ - - - (9)

Average deviation from mean return: $\sum Y_{th} = \lambda$
(where $\lambda = Y_{th} > 0$) - - -(10)

Maximum restrictions: $X_i \leq X_i^*$ - - -(11)

Non negativity constraints: $X_i, L_m, C_w, C_t, F_n, R_p, \geq 0$, - - - (12)

Where, the **parameters** are:

a_{ij} = area of land (hectares) used by one unit of the cultivated crop 'i' in jth bi-monthly season,

c_i = gross margin from one unit of crop activity (Rs/hectare),

c_{hi} = gross margin of ith crop activity in hth year (Rs/hectare),

CIW = Average canal irrigation water available on an average farm in hectare-cm,

f_i = fuel obtained from biomass of ith crop (Kcals),

f_{in} = fertilizer nutrient - nitrogen/ phosphorus (kg) required per acre by ith crop activity,

FLM = Amount of family labour available (man-days) in the mth month,

g_i = Mean value of the gross margin of the ith crop activity,

k_i = working capital required by one unit of ith crop activity,

l_{im} = labour used in mth month by one hectare of ith crop activity(man days),

LH = average land holding (hectare),

p_f = average market price (Rs/kg) of nitrogen/phosphate/potash fertilizers on nutrients basis,

p_m = average market wage rate of hired labour (Rs/man days) in the mth month,

p_r = average cost of pumping four hectare-cm of water,
p_s = average sale price (Rs/qtl.) of green fodder,
p_w = rate of interest on working capital (per cent/annum, for six month),

s_i = amount of fodder produced (qtls.) by unit crop activity,

w_i = amount of water required by a crop activity in one hectare of cropped area (in hectare-cm),

WC = amount of working capital (Rs.) available during the year,

Y_{th} = maximum value that average deviation from mean return can take on,

X_i^* = maximum possible area under certain crops like potato, sugarcane, paddy, fodder on an average farm of the Kurukshetra district of the North West India,

λ = average negative deviation from mean return (Rs.),

and, the **decision variables** are:

C_w = amount of working capital to be borrowed (Rs.),

F_p = level of fuel purchased,

F_n = amount of fertilizer nutrients - nitrogen, phosphate, potash purchased (kg.),

L_m = amount of hired labour (man days) in month,

P_w = amount of ground water lifted (hectare-cms),

R_s = amount of green fodder sold (qtls.) in the year,
X_i = level of ith crop activity (hectares),

Y_h = absolute value of negative total gross margin deviation from mean return in the hth year,

Z = value of the objective function.

The farm-environment related parameters that are relevant for future growth of agriculture in North West India and also incorporated in the above model are as under,

a) Soil degradation- Extraction of soil macro- nutrients,
b) Decline in groundwater table- Use of water during monsoon (July-October), and other period (November-June),
c) Biomass produced-crop residues in the system,

d) Stress on Common Property Resources (CPRs)- Availability of fodder & fuel from the system,
e) Social conflicts- regularity of employment, stability of farm income.

The present study incorporates interactions between different sub-systems of agriculture on an average farm in a LP framework. Farm-level interaction in a linear programming framework has been captured by several researchers (Pant and Pandey, 1999). In the present study alternate plans are obtained for an average farm by varying price, technology and institution-related factors. The farm-level evaluation has been undertaken for three situations namely: first, where an average farm is optimized with prices as prevailing during the reference period (1998-2003) referred to as existing situation; second, an average farm is optimized with the rationalized prices for farm inputs; and third where, farm resource are optimized with the changed input-output coefficients primarily to reflect alteration in technologies. This is in addition to the changes in price as in the second situation.

Farm plans are evaluated on the basis of a host of economic and environmental parameters that influence the long-term growth of agriculture in the region. Though these parameters assume different kinds of importance for different persons, the farmers' perception is important as it is they who respond to the policy changes. Farmers were asked about their perceptions on several economic, ecological and social indicators. These indicators with their weights on a scale of 100 are presented in Box 1. The present evaluation initially planned to incorporate these weights in the objective function and solve it in a goal programming framework as was done by Romero and Rehman (1985), and Romero and Rehman (1989).The author however, failed to accomplish it and instead the study discusses results obtained under alternate scenarios on the basis of the above indicators.

III Results and Discussions

The present section discusses the results of evaluation in different sub-sections. The first sub-section discusses primary and secondary benefits apart from the costs associated with alternate technological options; whereas, the second sub-section discusses farm-level evaluations in alternate scenarios.

3.1 Farm–level Benefits and Costs of Alternate Technological Options

The benefits and costs of alternate technological options, based on a combination of primary and secondary information is presented in Table 1. Information related to return and cost is based on primary data collected from sample households; whereas, stability of return is based on secondary information as obtained from Krishi Gyan Kendra (KGK). Information on various secondary benefits and costs are based on a combination of sources. Fertilizer statistics provide information on many parameters; this was further supplemented by technical information collected from scientists, extension-workers and progressive-farmers of the region. Information presented in Table 1 is not complete in the sense that it pertains to activities being practiced in the region; whereas evaluation of alternate options should ideally contain information on all possible activities that can be cultivated in the region at the farm level. The study therefore has made some difficult assumptions; these assumptions are discussed in appendices (Appendix 1).

As is evident from table (Table 1), sugarcane crop is associated with the highest return, while other crops with a decreasing order of return are potato, wheat, basmati, and non-basmati rice, cotton, rape-mustard, jowar, berseem, maize, sunflower, gram, bajra, and summer pulses. Most of the time high gross return for crops is associated with the high cost of production for these crops. On account of stability in return, performance of crops varies; some high return crops like potato and basmati rice are associated with high risk (instability) in return. There are exceptions too for example; wheat and non-basmati rice are high return crops these are also associated with the low risk (instability) in return. The reasons for low instability in return for the latter crops are known widely. The market for wheat and non-basmati paddy is assured in North West India; therefore market-induced price risk is less. This is reflected in a relatively stable farm return for these crops (for details see Jha 1996). This is however not the case with other crops like potato and basmati. The market price for basmati depends on distant markets in the country and abroad, whereas, the market price for potato depends on a mis-match between production and cold storage facilities of potato in the Kurukshetra district. Instability in return from potato and basmati is high on the above account.

A high allocation of land under wheat and non-basmati crops in fact highlights the importance of risk in farmers' decision. These crops are also associated with high variable costs; the high cost is however not a deterrent for the adoption of these crops in North West India. Acreage under some other crops is restricted on account of local constraints; in sugarcane, for example, acreage depends on the capacity of the sugar mill in that area. Similarly, the area under potato is constrained because of inadequate storage facilities for the crop. At the extreme end of risk-return combinations are crops like coarse cereals and pulses; wherein the return is low but instability in return is high. The sources of these instabilities are rooted in the production as well as marketing of these crops. The summer pulse presents an extreme example; uncertainty associated with the production of this crop has been so high that the acreage under this crop has not increased in this regard; though this has great potential as it is a short duration crop and can easily be inserted between wheat and rice crops during the April-May months. With the inclusion of pulse in the existing rice - wheat crop rotation, farmers may get extra income and the health of soil will also improve.

The ecological factors are more important from society's point of view; if resources are priced properly ecological degradation may get reflected in the private cost of production of farmers in the long run. It is generally believed that in the semi-arid region such as that of the NW India, the private cost of production of rice and sugarcane is under-valued, since these crops are water intensive and the private cost of irrigation through groundwater at the existing power tariff does not reflect the actual cost of draft of ground water. The nutrient uptake of crops from the soil is definitely a drag on the future agricultural growth of the region as chemical fertilizers added into the soil are not a substitute for organic fertilizers added into the soil. The chemical fertilizers do not improve the physical health of the soil; only a part of chemical fertilizers is absorbed by the crop[2]. In general, hybrid and high yielding seed varieties are nutrient intensive; whereas, pulse replenishes nutrients in the soil, these crops are therefore supposed to improve the physical health of the soil.

[2] In nitrogenous fertilizers like urea experimental results suggest that one third of urea applied in a field is consumed by the plant, another one-third is lost in the soil-subsurface while the remaining one third leaches down to pollute ground water (for details see Jha 2000).

Table 1: Principal Crops with Various Parameters on per hectare basis in the Study Area

Eco-Environ. Parameters	**HYV Rice**	**Basmati Rice**	**Wheat**	**Maize**	**Bajra**	**Gram**	**Kh'f pulse**	**Su'r pulse**	**Rape-Mustd**	**Sunflower**	**Jowar***	**Berseem**	**Sugarcane**	**Potato**	**Cotton(Hy)**
Crop durations	Jul-Oct	Jul-Nov	Nov-Apl	Jul-Oct	Jul-Oct	Oct-Jan	Jul-Spt	May-June	Oct-Jan	Jan-Aprl	Jul-Oct	Nov-Apl	Jul-Apl	Oct-Dec	May-Oct
Gross returns ('00Rs)	228.48	232.96	246.4	120.96	64.96	87.36	91.84	33.6	129.92	98.56	136.64	161.28	528.64	295.68	206.08
Variable Costs ('00Rs.)	141.12	123.2	109.76	80.64	53.76	58.24	60.48	24.64	69.44	85.12	107.52	127.68	250.88	183.68	105.28
Stability of Return (CVt)	26.88	103.04	11.2	38.08	67.2	51.52	56	64.96	44.8	58.24	0	0	24.64	85.12	44.8
water rq'nt (hac-cm)	170	175	40	85	55	20	50	20	25	15	90	60	190	35	70
i) Irrig'on du'ng monsoon	110	110	0	25	15	0	10	0	0	0	30	5	80	5	30
ii) Irrig'on - other	0	5	30	0	0	10	0	10	15	10	0	45	50	20	0
Nutrient uptake from soil															
i) Nitrogen (kg/hect)	124	74	114	59	8	0.5			42	42	24	53	174	74	198
ii) Phosphate (kg/hect)	31	19	18	14	3	15			21	21	9	10	15	18	65
iii) Potash (kg/hect)	166	98	113	80	27	300			53	53	40	43	177	129	206
Fuel ('000 kcals/hect)	1150	1400	1790	1250	620	500		400	400		140		830		2100
Fod'r (kg/hect)															
i) Dry Crude Protein	10	13	20	30	10	140		112	0	0	0	0	750	0	0
ii) Total Dig'ble Nutrients	620	800	182	1550	760	1000		700	0	0	0	0	8530	0	0
Employment (mandays)	110	112	56	64	58	38	40	32	40	50	72	96	135	110	100
i) Sowing & Harvesting	86	85	43	50	44	26	24	24	25	27	16	34	45	72	68
ii) Other operations	24	27	13	14	14	12	16	8	15	23	56	62	90	38	32

Note: In pulse coefficients related to nutrient uptake from soil is available for gram only, for the sake of convenience this coefficient has been assumed for *kharif* and summer pulse as well. On similar account the coefficient related to total digestible nutrients for *kharif* pulse is assumed as that of summer pulse. Absence of any figure in a box suggests that the particular crop does not contribute to the parameter in question.

Though the importance of crop residue from the view point of its contribution to fuel and fodder is perceived to have decreased with the commercialization of agriculture, some crops are still preferred on account of their contribution to the fuel and fodder basket of the farm. Crop residues have been traditionally used as important energy supplements while the recent hike in the price of mineral oils / fossil fuel, reemphasizes the role of crop residue as an important source of fuel energy. Fodder supplements from crop residues are also important considering the kind of pressure on land to meet the multiple demands of food, fibre and fodder in the economy. Popularization of buffalo-based herd is in fact a testimony to the importance of crop-residue as fodder in the existing farming system of the region[3].

Box 1: Important Economic Ecological and Social Factors with their weights in percent

Indicators	Weights
Economic	**70**
Gross Return	45
Stability of Return	20
Variable Costs	05
Ecological	**22**
Water requirements	12
Nutrient uptake	03
Fuel Supplement	02
Fodder Supplement	05
Social	**08**
Concentration of Employment	04
Amount of Employment	03

Rural employment definitely affects the social environment of the villages. Agriculture accounts for around three-fourth of rural employment in the country. Employment in agriculture is however skewed as demand for labour in crops is concentrated in selected agronomic operations. This concentration of labour demand varies across crops; for example demand for labour is more concentrated in paddy than potato. With a specialization of area under wheat and paddy crops, the concentration of labour demand has increased in the study area. The labour demand is concentrated both during the sowing and harvesting of paddy and wheat crops. The skewed demand for labour does not help in improving the rural unemployment situation of the region as farmers remain under employed for a large part of the year while they have to depend on migratory labour force during the above agronomic operations. These trends are not good for the social environment of rural sector. The present study therefore evaluates alternate technological options on the basis of labour absorption in crops and distribution of labour during crop seasons.

[3] One may note that amongst allied activities, more specifically livestock, buffalo is the most efficient converter of roughages (crop residue) to milk.

The above discussion suggests that primary and secondary benefits and costs obtained from crops vary. One can rank alternate technological options (crops) on the basis of a set of Economic-Ecological-Social indicators. Adoption of these options depends on various constraints and opportunities that prevail in a region. Alternate technological options are therefore evaluated in a farming system framework.

3.2 Farm-level Evaluation under different Situations

The present sub-section evaluates the impact of alternate price and technological options on an average farm of North West India. This also evaluates the role of institutions by studying the differences in the optimized solutions that are obtained with and without the region-specific institutional constraints[4]. The present evaluation adopts a farming system approach as this captures interaction between different farm activities and resources under farmers' control. The farm in the present analysis represents an average farm, synthesized from primary data collected from sample farmers during the year 2001-02; some of this information was further updated for the year 2003-04. The selection of farmers involves a multistage-stratified-random sampling technique illustrated in Appendix 2. The Economically-Ecologically-Efficient or E-Efficient plans present crop combinations as farmers try to use their resources optimally on the basis of two economic criteria, that is, maximization of gross margin (return) and parameterization of negative deviation from mean return (risk). The E-Efficient plans have been derived for three situations, termed as E-Efficient Plan-I to III.

In the E-Efficient Plan-I, resources are used optimally with the existing enterprise-mixes; input and output prices are the average price of farm input and output as it prevailed during the period (1999-2004). Though availability of resources and the resource utilization pattern varies across farm, the existing farm plan reflects resource use on an average farm. Certain land-based technological options are evaluated here for their

[4] A linear programming based optimization leads to specialization under the most profitable crop / crop rotation. At times these crops and crop rotation can not be cultivated to its full potential on various accounts specific to a region. Acreage under such crops in the above LP-based model is restricted to the existing area under an average farm of the study area. The difference in farm return obtained with specialized as compared to that with the constrained solution in fact shows return forgone on account of region-specific institutional constraints.

usefulness on an average farms[5]. This field visit suggests the scope present for incorporating pulses between wheat and paddy crop rotations. Selected farmers, it was seen, were also practicing a complete annual cycle of vegetables, fruits (*kinnow,* a citrus fruit), agro-forestry (eucalyptus, papular, *subabul* / acacia)[6]. Technical information on relevant parameters of these options is also collated during the field visit.

In E-Efficient Plan-II, resources are used optimally with the existing enterprise-mixes, while input and output prices are rationalized. Agricultural output prices in India are closely getting linked with the international prices; domestic prices during the period 1999-2004 were very close to international prices. During the above period, the domestic prices of agricultural commodities were by and large higher than the price of the leading exporting countries of that commodity in the world (Jha 2008). The Domestic price of agricultural commodities during 1999-2004 is therefore assumed to represent undistorted price of farm output. In the category of tradable farm inputs, the price of fertilizers other than urea is linked with the world prices; therefore these prices are assumed to have been rationalized in the present study. In the category of non-tradable farm inputs, the price of canal irrigation water and tariff of power used for agriculture are important. Several expert committees have deliberated over guidance for to guide about rationalization of prices for some of the above farm inputs. Rationalization of input and output prices is deliberated in details in Appendix (Appendix 3).

In E-Efficient Plan-III, in addition to the E-Efficient plan-II, the existing non-land based resource utilization pattern is altered to increase production and simultaneously conserve natural resources. In the present evaluation the resource utilization pattern is altered following the adoption of integrated pest and nutrient management (IPM and INM) practices. The IPM incorporates the conjunctive use of inorganic (synthetic) and organic chemicals. In North-West India evidences of crops wherein integrated pest and nutrient management are being practiced, though on a limited scale are paddy, wheat and cotton. Changes in the input-output coefficients of these crops on account of adoption of

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[5] Alternate land-based technological options in the present study are actually crops cultivated by the selected farmers of the region; these farmers are progressive and crops are cultivated in the study area only on a limited scale.

[6] In the study area, large farms frequently practice agro-forestry with perennial trees like popular and eucalyptus; whereas, certain small farms are growing vegetables for commercial purpose.

the IPM are therefore considered in Plan –III (for details see Appendix 4, Appendix Table 2).

3.2.1 The Existing Farm Situation

The existing situation in the second column of Table 2 depicts crop-combination on an average farm of 2.7 hectare during the survey year. The existing crop enterprise-mix in the study area is dominated by paddy and wheat crops; there is no significant difference across farms on this account. The next most important crop rotation in the study area is fodder consisting of jowar (*chari*) and berseem crops. In fodder, a different trend across farm sizes is visible, the proportionate area under fodder is lesser on large as compared to the smaller farm. This supports the widely held view that the intensity of livestock is greater on a small farm. A similar trend across farm size is evident in vegetables, while a reverse trend is evident in agro-forestry. Agro-forestry, vegetables unlike paddy, wheat and fodders are not cultivated on all farms. The percent area under these crops is therefore small on an average farm.

A complete rotation of vegetables has been extremely profitable on small and marginal farms where the intensity of labour is very high. Some of the important vegetables being cultivated in the study area with its duration given in parentheses are as follow: pea and cauliflower (September – January), ladyfinger, bottlegourd, *tinda* (February-June), tomato (January-April), *Arbi* (March-September). Cultivation of vegetables has been more profitable in the urban vicinity as better prices are assured in such a region. Eucalyptus, papular, subabul (*acacia sp*) are important plants being grown in the private and community land, the same is referred to as agro- and social-forestry, respectively. In the study area selected, large and medium farmers have adopted agro-forestry in which the farmers either dedicate a significant part of their land exclusively to above plants (eucalyptus and papular) or these plants are cultivated at the edge of their agricultural land. Plants under agro-forestry as compared to annual agricultural crops have a longer gestation period. These plants are less labour intensive and the requirement of labour for these crops as compared to seasonal crops is less skewed. The labour requirement for plantation crops is distributed throughout the year in such a way that 'attached worker' can do this work efficiently[7]. All the above conditions related to agro-forestry in fact suit large farmers. Agro-forestry provides a regular supply of fuel for farm family. It is therefore important for the household energy security and also for the long-term growth of agriculture. However, with a dearth of desired information on the technical coefficients of these plants with respect to several economic, ecological and social indicators, these plants along with certain other crops have been considered as pre-determined activities in the present evaluation.

Cultivation of pulse improves soil health and the prices of pulse are increasing consistently. Yet, the pulse crop is not seen as being very profitable on an average farm of the region. In the *rabi* season, gram to a lesser extent has found a place in some of the large farms of the region. Field visits in North West India however, suggest ample scope for a successful cultivation of summer pulse between April-June. In the wheat-paddy based crop rotation, land remains fallow during the above period. The Yield of these crops however has been highly unstable on account of a sensitivity of these crops to an abrupt rise in temperature during the crop season. The crop is also water-intensive as it is cultivated during the summer season (May-June).

Oilseeds are among the other agricultural commodities, the prices of which are increasing consistently. Yet, it is not as profitable as the paddy-wheat based crop rotation. In the *rabi* season, rape-mustard to some extent has found a place on an average farm. In the mid-nineties, sunflower to a greater extent has replaced late-sown wheat. This had a favourable effect on groundwater resources as well (Jha 2000). The area under sunflower has however decreased in the subsequent years. Field visits to the region show that the yield of sunflower has decreased in the recent period. In ascribing reasons for a decline in yield, farmers doubt the quality of seeds that is being supplied through the private seed agencies as sun flower seeds are of hybrid varieties and in a hybrid variety the quality of seed assumes greater importance. Hybrid seeds also need to be replaced each year. These are some examples of production-related constraints in crops other than paddy and wheat.

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[7] Attached workers are employed on a farm generally for a year with a pre-agreed generally fixed amount of wage income during the contract period. This arrangement is in vogue on large farms where family workers are insufficient to manage / operate farm-related work.

Commercial crops like potato and sugarcane are highly profitable and involve less production risk; yet, these crops can not be cultivated to their full potential in the study area. Field visits to the study area suggest some institutional and infrastructure related constraints at the local level. Area under sugarcane for example, depends on the crushing capacity of the only sugar mill in the district. Similarly, the area under potato is constrained on account of the insufficient storage facilities in the district. Most of the crops other than fine cereals have faced similar institutional constraints in the district. Whereas, the long-term growth of agriculture in the North West India is often believed to rest on reducing area under fine cereals. The present situation requires a removal of the above constraints in the region. In the present linear programming-based evaluation these constraints have entered as maximum constraints on the selected activities; the same is referred to as institutional constraints.

3.2.2 Optimization of Resources with the Existing Technology and Price

Plan – I presents optimization results (solution) obtained from the existing situation on an average farm of the region. These results are presented in Tables 2 and 3. The third column of Table 2 presents a mix of enterprises that simultaneously maximize farm return and parameterize negative deviation from return; the third column of Table 3 presents the consequences of the above enterprise mixes on utilization of resources other than land, this column also presents information on several variables related to economic, ecologic and social environment of an average farm of North West India. As is apparent from Table 3, increase of return in Plan -1 over the existing (non-optimized) Plan has been only marginal indicating that the existing resources on an average farm of the region is utilized efficiently considering the region-specific institutional constraints on an average farm of the region.

In the LP-based analysis, optimization as usual leads to a solution and the same is presented in the above tables; an understanding of different steps in optimization techniques however highlight the role of institutions and the importance of risk in farm decision. Optimization without incorporation of constraints related to negative deviation from mean return provides a set of enterprises dominated by basmati rice and vegetable based crop rotations. In this solution, farm return has increased significantly but risk associated with the above enterprises has also increased significantly. Though these results are not apparent from the above table since negative deviation from mean return is not incorporated in the model when the above results were obtained. With the incorporation of negative deviation from return, as one of the constraints in the present linear programming model, the area under dwarf rice increased at the cost of basmati rice and the area under wheat increased at the cost of other *rabi* crops. It is needless to emphasize that wheat and paddy as compared to other competing crops in the respective season involve minimum risk on an average farm of North West India. This specialization with the incorporation of negative deviation from the mean has a favorable effect on both the economic indicators namely: return and risk. This has however, an adverse impact on the ecological indicators especially, water.

Table 2: Emerging Crop-combinations in Alternate Situations at an Average Farm (2.7 hectare)

Crops	Existing	Plan-I	Plan-II	Plan-III
Paddy - HYV	1.5	1.9	0.5	1.2
Paddy – Basmati	0.4	0.0	0.0	0.0
Wheat	1.9	1.9	1.0	1.2
Maize	0.01	0.2	0.5	0.3
Bajra	0.00	0.00	0.0	0.0
Pulse - rabi	0.02	0.00	0.00	0.0
Pulse - kharif	0.00	0.00	0.00	0.0
Pulse – summer	0.02	0.1	0.5	0.2
Rape-mustard	0.03	0	0.4	0.5
Sunflower	0.1	0.1	0.5	0.3
Sugarcane	0.1	0.1	0.1	0.1
Potato	0.08	0.1	0.5	0.3
Cotton	0	0	0.4	0.5
Jowar chari	0.41	0.41	0.41	0.41
Berseem	0.41	0.41	0.41	0.41
Vegetables	0.07	0.07	0.07	0.07
Fruits	0.01	0.01	0.01	0.01
Agro-forestry	0.03	0.03	0.03	0.03
Total Cropped Area	5.11	5.33	5.33	5.53

The effect of the wheat–paddy crop rotation on water and similar other resources have been well recognized and there have been efforts to restrict the area under these crops. In the present LP-based analysis also, the area under these crops is restricted. Similar constraints are often desired to limit area under some of the other profitable crops since linear programming leads to specialization. These constraints reflect institution-related limitations for crops in the region. In the paddy and wheat crops this includes ground water scarcity. After imposition of such restrictions, maize-potato-sunflower has emerged as the next best alternative. However, even with an increase in the intensity of land use to 300 per cent, the above crop rotation is not as profitable as the wheat-paddy based crop rotation. In this situation it emerges that farm return has decreased marginally with the substitution of a maize-potato based rotation for a paddy-wheat based crop rotation. The difference in return between a specialized plan obtained without maximum restriction or local constraints and farm return derived after incorporation of maximum restriction indicates return foregone due to local constraints. The above analysis shows that crop enterprise mix changes with the incorporation of constraints related to risk in farm enterprises and also region-specific institutional constraints on an average farm. With the changes in crop enterprise mix, utilization of resources other than land has also changed; these changes have an effect on farm return, risk and similar other variables, that influences the long-term growth of agriculture in the region and is presented in Table 3.

Table 3: Evaluation of Alternate Situations on the basis of different Economic, Ecological and Social Parameters

Parameters	**Existing**	**Plan-I**	**Plan-II**	**Plan-III**
Economic parameters				
Farm return (‘00Rs)	566.87	567.74	483.76	586.86
Negative Deviation (‘00Rs)	139.16	110.67	211.42	182.16
Ecological parameters				
Total water requirement (hacm)	506.7	518.6	332.2	438.8
Irrigation-monsoon (July-Oct)	239.4	244.2	107.8	184.1
Irrigation-otherseas. (Nov-June)	90.2	86.4	82.3	80.8
Nutrient mining (kg)				
Nitrogen	514.2	536.7	421.5	523.1
Phosphate	106.1	110.4	106.9	131.0
Potash	596.5	629.9	467.6	613.3
Fuel derived (‘000 kcals)	6138.8	6198.8	3596.6	4454.5
Fodder obtained				
Dry crude protein	143.5	153.5	176.1	146.6
Total digestible nutrients	2582.4	2839.4	2544.1	2493.0
Social parameters				
Employment - total (mandays)	432.7	439.2	390.5	439.6
Emp- Sowing and harvesting	291.5	298.9	242.3	284.6
Emp- other operations	141.2	140.3	148.2	155.1

3.2.3 Optimization of Resources with the Rationalized Prices

In the present evaluation the next exercise is about assessing the impact of alteration in farm input and output prices on optimal allocation of resource for an average farm. Alternate prices suggested in the present analysis are the rationalized prices of farm inputs and outputs. The rationalized prices to a large extent depict the shadow prices. In the present analysis, rationalized price is significantly lower than the shadow price on account of an assumption that the current level of subsidy in farm input (as in the year 2001-02) would not be abolished altogether. Fertilizer subsidy has been assumed to reduce by half (for detail, see Appendix 3). Similarly, on farm output front, though there is growing evidence of an increased integration of the domestic market with the world market (Appendix 3); differences in domestic and world prices would remain on account of certain trade barriers that are necessary to protect domestic farmers and consumers from the volatility of the world agricultural market.

For rationalization of farm input prices, the present evaluation targets urea and power tariff for agriculture purpose. Though prices of urea in the world market are highly unstable, various forecasts available indicate that the world price of urea (*fob*) in the medium-run will average at around US$ 140 per tonne. This would translate prices *(farm-gate-prices)* of urea at around Rs 7 per kg in the year 2003; whereas, the domestic price of urea during the above period was Rs. 4.80 per kg. Rationalization of fertilizer prices ignores the price of chemical fertilizers other than urea since flat concessions to these fertilizers have a less distortionary effect on the domestic market of fertilizers (Jha 2001). The present evaluation assumes that the total subsidy to fertilizer will be equal to the concessions exclusively provided to non-urea nitrogenous, phosphatic and potassic fertilizers in the year 2003-04 (details in Appendix 3).

About rationalization of power tariff there is almost a consensus that tariff of power for agriculture purpose should reflect 50 per cent of the pooled cost of power where the cost is as reported by the respective state electricity boards. Alteration in tariff of power for its use in agriculture will increase the cost of irrigation with the ground water; this may have other effects as well, such effects are however ignored from the present evaluation. There is a dearth of estimate that shows the effect of changes in power tariff on the cost of irrigation with groundwater. In this situation farmers were asked directly about the likely increase in the price of irrigation with the alternate tariff of power. Farmers in the study area were of the opinion that with the aforesaid increase in the power tariff, the cost of irrigation will almost double. The present analysis therefore considers Rs. 140 as the cost of irrigation for one hectare of land to a depth of 4 cm; this 4 ha-cm is also the volume of water widely believed to be consumed in one irrigation of field crops in the region.

The crop combination arrived at with the altered prices is presented in the fourth column of Table 2 mentioned as E-Efficient-Plan-II. It is apparent from table that the area under rice and wheat has decreased and that of small duration crops has increased. This has resulted in an increase of cropping intensity on an average farm. The most important crop rotation that emerged in the present policy scenario was of the summer pulse-maize-potato-sunflower crops. Summer pulse can easily be inserted into any crop rotation since there are not many crops that can be cultivated during the above period. With the incorporation of summer pulse cropping intensity increased to 400 per cent. This level of crop intensity is difficult on many accounts. Alteration in crop rotation had a limited effect on groundwater resources; one of the significant effects has been the decline in water requirement during the monsoon season. In seasons other than the monsoon, the demand for water has not decreased significantly as there is an increase in cropping intensity. This increase in cropping intensity will encourage mechanization and in the long-run this will adversely affect physical health of soil. Cotton-rapeseed/ mustard is another crop rotation that has emerged as being important.

The above changes in cropping pattern have however a significant positive effect on fuel and fodder availability and also on absorption of labour (col. 4, Table 3). Linear programming-based optimization has led to specialization under potato and cotton-based crop rotation. The profitable levels of potato on an average farm is however restricted on account of local constraints referred to earlier. The farm return in Plan-II has decreased primarily because of an increase of costs. The farm return has interestingly not increased in spite of a significant increase of cropping intensity. This suggests that rationalization of agricultural prices will neither increase farm returns nor reduce the extent of degradation of natural resources. The pattern of resource degradation has only changed.

3.2.4 Optimization of Resources with Rationalized Prices and Altered Technologies

The role of technology in improving productivity while alternately reducing the unit cost of production and conserving natural resources cannot be overemphasized. The present analysis in E-Efficient Plan-III tries to assess the role of technology in solving problems related to agriculture in North West India. One of the biggest challenges in the study area has been posed by the increased use of resources both natural (water) and artificial (chemicals). Paddy and wheat-based crop rotation is often blamed for these problems as these are highly resource intensive. The scope of changing the above crop rotation with various land-based technological options has been assessed in the previous two plans. There is also present ample scope for reducing the extent of use of resources other than land. Though many resource conserving technological options are suggested for the region, only a few of them have been adopted at the level of field and Integrated Pest Management (IPM) is one of them[8].

The E-Efficient Plan-III evaluates the likely changes in the pattern of resource utilization following an adoption of IPM. In a linear programming exercise, adoption of IPM will alter the technical coefficients of the selected crops for which IPM has been adopted. The field-based evaluations of IPM vary across regions. For North West India such evaluations are available for crops like rice, wheat, rape-mustard and cotton. In spite of the limited crop-specific results, the IPM has been assumed as the most important resource conserving technology for the present evaluation; since such technology in the study area is desired the most for paddy and wheat crops, the crop-specific results are incidentally available for these crops. The E-Efficient Plan-III present optimization results obtained following alteration in the technical coefficients for paddy, wheat, rape-mustard and cotton. It may be noted that the above alteration in technical coefficients is in addition to alteration in farm input prices as in Plan-II.

The optimization results in Plan-III have shown an increase in area under paddy and wheat crops; while acreage under these crops had decreased in the earlier plan (E-E-Plan-II). Area under summer pulse has also increased; in other words, paddy-wheat-summer pulse emerged as the best crop rotation. Considering the implications of crop

[8] There is sufficient scope of adopting Systems of Rice Intensification (SRI) as it reduces the intensity of resource use in paddy. In North West India much of the resource degradation is on account of intensive agricultural practices. The SRI was however, not reported during the field visits of the study area (see Jha 2008).

rotation on ground water, the maximum limits were imposed on paddy. The second best possible crop rotation that emerged was maize-potato-rapeseed. The optimal level of the above crop rotation was however restricted on account of a limited storage capacity for potato. Subsequently, cotton and rape/mustard emerged as the next best alternative in Plan III. In the above crop rotations, maize and cotton are important crops cultivated during *kharif* season; there is sufficient scope of adopting genetically improved maize and cotton crops in the region[9]. Following adoption of such technologies, the relative profitability of these crops will increase and they can replace the paddy-based crop rotation in North West India.

In the above evaluation exercises, fodders, vegetables and fruits have entered as predetermined variables since ecological parameters related to these crops and desired for present evaluations are not available. In North West India the mixed farm has been the most dominant farming system and it is obvious that fodder is profitable on an average farm. In the study area vegetables have been relatively more profitable on small farms; whereas agro-forestry is preferred more on large farms. The present evaluation assumes that the above crops would remain profitable on an average farm; these crops have therefore been considered as the pre-determined variable in the linear programming exercise. Since these crops are predetermined variables, the area under these crops has not changed on an average farm.

The above analysis suggests that price, technology and institution-related interventions have a significant effect on crop-enterprise mixes and so on various parameters related to economic, ecological and social environment that influence the long-term growth of agriculture in North West India. A comparative account of these indicators related to economic, ecological and social environment in alternate plans is presented in Table 3. The economic parameters: return and risk in E-Efficient Plan-III improved over the E-Efficient Plan-II. Farm return in Plan -III was better than the E-Efficient Plan-I, though this has been accompanied by a higher negative deviation in

[9] The present evaluation has not considered a transgenic cotton variety like Bt cotton (ball worm resistant transgenic cotton variety); at the time of the field visit Bt cotton was not adopted in the study area. Though Bt cotton is now considered as the most important technological breakthrough of the recent past, experiences with certain developing countries suggest that maize is close to a similar technological breakthrough. The present evaluation ignores such varietal improvement. Technology here refers to various resource-conserving technological practices for the same set of varieties that is being practiced in the region.

mean return. The ecological parameters have two important components namely; resource degradation and crop residue as supplements to fuel and fodder. On account of resource degradation, Plan-III is better than Plan-I; whereas, on account of fuel and fodder supplements, Plan –III is not as good as Plan-I. The social environment related indicators in Plan –III have definitely improved over the earlier plans.

The above comparison suggests that rationalization of prices alone will not lead to a sustained growth of agriculture in North West India. This has to be effectively supported by the suitable technology and appropriate institutions related to agriculture. The appropriate institution referred to here is the arrangement that creates opportunities and also restricts use of specific scarce resources. The present evaluation clearly shows that rationalization of power tariff, as is generally believed, has not resulted in lesser degradation of natural resources like ground water. Government may have to come out with a stringent law that will restrict the use of ground water at least in the dark region of North West India.[10] In brief, the present evaluation highlights that technology and institution are as important as price in improving the economic, ecological and social environment of the average farm in India.

IV. Conclusions

The present study evaluates the effect of price, technology and institution-related policies for an average farm (2.7 hectare) in North West India. The present evaluation assumes that farmers in response to the changes in agricultural prices would adopt alternate technological options taking note of the existing institutional setup. The study uses linear programming techniques to incorporate several economic, ecological and social factors that influence the long-term growth of agriculture in North West India. The above analysis shows that the average farm in the study area is largely allocating resources efficiently; instances of sub-optimal use of certain resources prevail on account of region-specific institutional constraints. With the rationalization of agricultural prices, prices of urea and power tariff for agriculture have increased significantly. This has resulted in increase of cost and decrease of farm return, though on account of ecological and social

[10] On the basis of use of ground water, a region is termed dark if the draft of ground water is more than 85 per cent of utilizable resources of ground water. All blocks under the Kurukshetra district are 'dark' on the basis of use of ground water resources.

environment the situation has improved marginally following price rationalization. With the increased prices of farm input farmers would adopt certain resource conserving technological options like IPM. Adoption of IPM in a LP framework changes the input-output coefficients; optimization with the changed input-output coefficients has resulted in a different crop enterprise-mix and improvement in economic, ecological and social indicators that are important for the long-term growth of agriculture in the region.

The present evaluation suggests that rationalization of price alone is not sufficient for the long-term growth of agriculture in a region. A sustained agricultural growth warrants suitable resource conserving technology and favourable institutions that unlock the region-specific local constraints specific to the use of a particular resource.

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Appendices

Appendix 1. Assumptions related to the Economic and Ecological Parameters of Important Crops in North West India

The Gross returns and Costs associated with the individual crop are based on the primary data collected during the survey of the present study since returns and costs of production of crops as available from the secondary sources (Commission for Agricultural Costs and Prices, CACP), are not there for many crops. Another economic indicator in the present evaluation is stability in return. The coefficient of variation (CV) is generally accepted as a measure of instability; incorporation of CV in a programming framework however makes the objective function quadratic or one that can not be solved through linear programming techniques. Hazell (1971) has suggested negative deviation from mean / trend return as a linear alternative to coefficient of variation (CV). The present study is based on a linear programming technique and therefore has chosen a negative deviation from mean / trend return (NDM) as an indicator for stability of return. It need not be said that the lower NDM would indicate a stable return. The NDM is computed from the cost of cultivation data as available from the Krishi Gyan Kendra (KGK) of the Kurukshetra district. The average NDM has been worked out from the data of the previous six years.

Water requirement and nutrient mining are important ecological parameters considered in the present evaluation. In an optimized plan, the total water requirement is an aggregate of water required for individual crop in hectare-centimeter; this also includes monsoon rain in hectare-cm. Water requirements for individual crop have been worked out after consultation with scientists and extension workers based on the KGK of the selected district. The total water requirement follows sub-headings like irrigation water required during monsoon (June 15 to October 15) and non-monsoon period (rest of the period). This differentiation is necessary since it is easy to get irrigation water from canal or tube well during the monsoon season. Nutrient uptake from soil is based on the various studies cited in the Fertilizer Statistics. Many estimates for nutrient uptake are also presented in the aforementioned book under different tables. Since these estimates are pooled from different sources, inferences on account of draft of nutrients may be drawn with caution.

The secondary benefits received from crops can be many. The present study has tried to parameterize these benefits from crop-residues into three broad headings namely, fuel, fodder and fertilizer nutrients. These estimates are based on the studies of ICAR (1980), Healley and Soffe (1988) as cited in Parikh J., R. Ramanathan, J. P. Painuly (1993). "Energy, Agriculture and Environmental Interactions: The Case of Rural India" in Parikh (edited) Energy Models for 2000 and Beyond.

Total employment in man days provides aggregation of employment from crops cultivated on an average farm of North West India. Employment in man days depends on the level of mechanization. The present evaluation presumes a moderate level of mechanization wherein land is prepared by tractor and other crop-based operations are performed by manual workers. This is the practice for bulk of the farmers in the study area, though some large farmers combine both for harvesting of wheat. The requirements of labour for important crops like paddy and wheat is concentrated on sowing and harvesting seasons of the crops. A relatively high labour requirements during the above period can not be met by the village based labour force, hence agriculture becomes dependent on migratory labour. This dependence of agronomic operation on the migratory workforce has various implications, which constrain the social environment of village.

Appendix 2. The Sampling Procedure for Farm-Level Evaluation

The selected district, Kurukshetra, has been studied for heterogeneity with respect to cropping pattern and the natural resource status. The difference in the relevant parameters was not significant for *tehsils* of the district. In spite of this two clusters of villages, each cluster of three villages was selected randomly. The selected villages in Cluster I are Ramgarh, Pratapgarh, and Sanwla; whereas, in Cluster II Alampur, Dayalpur and Salarpur villages were selected. A complete enumeration of selected villages was undertaken. A list of all households with operational holdings in the villages was prepared. These households were categorized into three groups -small, medium, and large by adopting the cumulative square root method of stratification. The combination of crops and dairy has been identified as the most important enterprise-mix in the sample household. Again, a list of farmers with the above enterprise mix in each of the above categories is prepared, arranged in an ascending order and finally, 60 households based on probability proportionate to the size of holding in each of the three categories of households are selected. Primary data regarding the technical requirements of inputs and outputs of farm activities and details of resource constraints on farm have been collected through a well-structured and pre-tested questionnaire. Farmers were interviewed with a detailed and pre-tested questionnaire to assess their resource utilization pattern and also their opinion about various factors plaguing the agricultural development of the region was sought. The average farm situation is created from this information.

Appendix 3. Alternate Prices Considered in the Present Evaluation

Alternate prices suggested in the present analysis are the rationalized prices of farm inputs and outputs. Though rationalized prices to a large extent depict shadow prices, assumptions in the present analysis are such that rationalized prices are significantly lower than the shadow prices of respective farm inputs and output. For tradable farm inputs the world price reflects the shadow price. Rationalized prices in the domestic market would be lower than the world price since farm input subsidy in India would not be abolished altogether.

In tradable farm inputs, the present evaluation targets urea for hypothetical rationalization. The prices of phosphatic and potassic fertilizers are already integrated with the world market. In these fertilizers, subsidy is in the form of direct flat concession to imported and domestically produced urea. There is no controversy on the above mode of subsidies (flat concessions) for these fertilizers. Prices of these fertilizers remain as it was in the year 2001-02. This presumes that the amount of subsidy to these fertilizers in the particular year would continue and this is the total amount of subsidy to chemical fertilizers in the country. This assumption is not irrelevant considering the integration of domestic prices of these fertilizers with the world market. The above assumptions also facilitate an arrival at the hypothetical price for urea in the following way. In urea as of now subsidy is in the form of difference between the farm gate price and the accumulated cost of urea. A large part of the consumption of urea in the country is the domestically manufactured urea (For non-urea fertilizers, subsidy is in the form of direct flat concession to imported and domestically produced urea.) The above assumption about fertilizer subsidy also takes note of issues such as benefits of fertilizer subsidy go to industry rather than to farmers. The present analysis assumes that flat concession would be the mode of subsidizing fertilizers in the forthcoming years. This further assumes that (even in the worst situation) the total fertilizer subsidy for urea and non-urea fertilizers would never be less than the concessions exclusively provided to the phosphatic and potassic fertilizers in the current year (2001-02). In the year 2001-02, the total concession to the phosphatic and potassic fertilizers was around 50 per cent of the total fertilizer subsidy; this assumption has eased the present investigator from making more difficult assumptions in the present analysis. The above assumption implies that the farm gate price of urea will reflect the world urea price with a minimum distortion (if the flat concession prevails). In this backdrop the question arises as to what would be the world price of urea in the present analysis? Though prices of urea in the world market are highly unstable, various forecasts indicate that the urea price (fob) in the world market will average at around US$ 140 per tonne. This translates urea prices at farm gate at around Rs7 per kg, while the price of urea in the year 2001 was Rs. 4.80 per kg. In the present analysis, the prices of fertilizers other than urea have been assumed as the base level of the year 2001.

In the non-tradable farm input power tariff for agriculture purpose is an important input that needs rationalization of prices. Tariff of power for its use in agriculture has been extremely low and is therefore targeted for rationalization in the present study. Though alteration in power tariff has different implications; its implications for the cost of irrigating water through groundwater has been assumed an important in the present study. The Price of irrigating a field crop is low in North West India. During the year of the present survey, the cost of irrigating one hectare of land through groundwater was Rs 70 per irrigation. The volume of water in this irrigation varied from three to five cm / inch of depth for one hectare / acre of cropped area. The present study therefore assumes that the volume of water per irrigation of field crop in the study area is around 4 hectare-cm or 4 acre-inch. The above price is definitely not based on the scarcity of water in the region. It was clear during the survey that the cost of irrigating water is a function of power tariff and the cost of establishment of tube-well. The rationalization of power tariff, which is essentially about hiking the power tariff for agriculture, would lead to an increase in the cost of irrigation.

The basic question is what would be the rate of power tariff for agriculture? In relatively less tradable commodities like power, the cost of generating power should be reflected in the power tariff for its use in agriculture. The chances of recovering the full cost of generation of power from power tariff that is charged from farmers are remote at least in the medium run (next seven to ten years). In the year 1996, a Chief Ministers' meeting on power tariff for agriculture provides important guidelines about rationalization of power tariff. In the above meeting, there was almost a consensus that power tariff for any sector inclusive of agriculture cannot be less than 50 per cent of the average cost of supply of power. There is dearth of evidence that shows the effect of power tariff on the cost of irrigation from groundwater. Ground water market in the study area is far from perfect. In this situation, farmers with tube-wells were directly asked about the likely increase in the cost of irrigation with the proposed hike in power tariff. The farmers were of the opinion that with the aforesaid increase in the power tariff the cost of irrigation will almost double. The present analysis therefore considers Rs 140 as the cost of irrigation of 4 hectare-cm of water.

Application of above assumption for a crop like paddy shows that the cost of irrigating a paddy field in the study area would be Rs. 14000 (desired number of irrigation during entire crop season is 10). This is almost 5 per cent of the gross value of paddy (around 25000 per hectare). The High Power Committee on Irrigation pricing headed by Vaidyanathan suggests that the cost of irrigation should be at least 5 per cent of the value of output of crops It may however be noted that the above recommendation about the price of irrigation is in the context of canal irrigation.

The protection coefficient trend in Appendix Table 1 suggests an increase in the integration of the domestic market with the world market during the reference years. A limited difference in domestic and world price, as is reflected with the protection coefficient, closer to one would probably remain depending on the volatility of the world prices. That the domestic price of a commodity is higher or lower than the world price would depend on that particular commodity is importable or exportable for the country. A lower price for an exportable commodity would remain on account of imposition of periodic restrictions on exports; whereas for importable commodity, import tariff rates are fluctuated / moderated within the bound limit, to balance the need of the consumer and producer. After carving out a list of 'sensitive commodities', the above trade measures do not appear to be in disagreement with the provisions of the WTO Agreements. Such periodic restrictions on the bulk of important agricultural commodities would therefore continue to protect domestic farmers and consumers from the volatility of the world agricultural market. On the above account, differences in domestic and world price would continue. This is true for most of the farm outputs in agriculture. Therefore the domestic prices of agricultural commodities in the year 2001-02 tend to reflect the opportunity cost of tradable agricultural output from India.

Appendix Table 1: Nominal Protection Coefficient (NPC) Trends for Selected Commodities

Commodities	Nominal Protection Coefficients					
	1992	1996	2000	2001	2002	2003-04
Paddy	0.90	0.82	1.10	1.14	1.28	1.20
Wheat	1.02	0.94	1.14	1.04	1.10	1.12
Maize	1.14	0.86	1.18	1.3	1.24	1.05
Sorghum	1.10	0.86	1.10	1.16	1.25	1.22
Cotton	0.81	0.83	1.06	1.15	1.12	0.91

Note: These estimates are for the leading producing state of the commodity. For example, Punjab for rice and wheat; Uttar Pradesh, Rajasthan, Gujarat, West Bengal and Andhra Pradesh for maize, sorghum, cotton, jute and tobacco, respectively (Jha 2008a).

Appendix 4. Alternate Technological Options for Farm-Level Evaluation

Adoption of any technology changes the input-output coefficients. Therefore technological options in the present evaluation refer to distinctly different combinations of input and output. In a linear programming framework this is reflected with the alteration in input-output coefficients. The changes in input-output coefficients are often specific to particular farm input / resource. Alternate technology for the farm level evaluation has been categorized as land and non-land based technological options. The same is discussed in brief in following paragraphs.

4.1A Land-based Technological Options

In the land-based technological options land is the basis of categorization of technology. Alternate land-based technological options referred here are different crops / varieties being cultivated in the study area or that have potential to be cultivated in the selected district of the state. The duration of the crops mentioned in Table 1 is as it is cultivated in the selected district. Crop seasons vary marginally across districts / regions and varieties and these presented in Table 1 are for the most important variety of the region. Crop seasons also vary as per purpose of cultivation. In this context it may be mentioned that some of the crops have alternate uses.For example Jowar in the study area is more frequently used as fodder rather than grains; similar is the case for berseem also.

In pulses, seasonality is reflected in prefix; *rabi* pulses for example is cultivated during *rabi* season; in the study area, *rabi* pulse is dominated by gram. In Kurukshetra, pulses are cultivated sparingly in summer and *kharif* seasons. Examples of *kharif* pulses are moong and *mash* whereas, pulses for summer season are primarily moong. Lentil is common in both, *kharif* and *rabi* seasons.

4.2B Non-Land Based Technological Options

There are numerous suggestions as far as alteration in the existing pattern of utilization of non-land based resources is concerned. Some of these are precision farming, systems of rice intensification. Though the efficacy of these practices is reported from certain parts of the country, instances of adoption of these practices are not reported from the selected district of North West India. In the context of resource conserving technologies, the integrated pest and nutrient management (IPM) programme holds promise in the study area. IPM encourages the conjunctive use of synthetic and organic chemicals. Advantages of adoption of integrated pest and nutrient management practices are well documented. The findings are often region specific. In Northwest India integrated pest and nutrient management is reported to have been practiced and also yield a significant results in the case of paddy, wheat, rape/mustard, pigeonpea and cotton. Evaluation of IPM by and large suggests that the yield of crop increases, the cost of production decreases and also structure of cost changes following adoption of IPM.

The cost of production increases on account of increased use of farm yard manure (FYM) / organic fertilizers while the cost of production decreases on account of lesser use of chemical fertilizers and insecticides. The cost of production is also reported to have increased with the increased use of labour. Adoption of IPM increases the use of labour more specifically, family labour as many of the bio-fertilizers / pesticides used in IMP are produced in-house. Preparation of such produce requires small but intermittent supply of labour during crop season. With the adoption of IPM, farm return increases on account of both increase in yield and decrease in cost. The benefits of IPM are reported to have been the maximum for those crops wherein chemical fertilizers / insecticides are used intensively for a longer period of time. Though it is difficult to exactly quantify the changes in the use of farm inputs and outputs following adoption of IPM, the present evaluation after review of some studies has tried to quantify changes over the existing practices in the following way (Appendix Table 2).

Appendix Table 2. A Farm-Level Impact of Adoption of IPM in Percent Change in IPM over Non IPM Farmers

Parameter	**Paddy#**	**Paddy**	**Wheat**	**Cotton**	**Pigeonpea#**	**Cotton#**
Farm Yard Manure	+2.6	+25.0	+15.0	+45.0	+45.9	+45.0
Chemical nutrients	-5.6	-20.0	-25.0	-5.6	-9.8	-5.6
Plant protection chemicals	-4.6	-25.0	-40.0	-34.0	-53.7	-67.6
Human labour	+4.7	+6.0	+8.0	+8.0		+8.0
Cost of cultivation	-5.8	-17.0	-22.0	-22.0	-25.6	-30.0
Yield	+8.9	+5.0	+8.0	+10.0	+18.2	+18.3
Net return	+30.4	+32.0	+38.0	+42.0	+161.2	+376.1

Note: Sign # shows that estimates for the respective crop are reported from certain studies like Ramarao e*tal* 2007; whereas estimates for other crops in many columns are arrived at after consultation with scientists of selected research institutes and also field-level workers in the study area.

Appendix 5. Institutions in the Present Evaluation

Though institutions are defined in different ways; institution in the present analysis is seen as a formal or informal contract that facilitates the production of agricultural commodities on an average farm of North West India. Field visits during the present study suggest that acreage under potato may increase with the increase in the storage capacity of potato in the district. Similarly, the area under sugarcane will increase with the increased crushing capacity of the sugar mill in the region. The present evaluation is based on the linear programming technique. A linear programming based optimization tends to lead to specialization under the most profitable crops, the therefore area under potato- and sugarcane-based crop rotations have increased under specific situations on an average farm of the study area. Acreage under these crops however can not be allowed to grow infinitely on account of the above crop-specific constraints. The profitable levels of these enterprises are constrained with the incorporation of maximum constraints on sugarcane, potato and similar other crops.

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