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Estimating Positive Externalities of Nitrogen Fixation by Pulses§

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Abstract

Pulses are important food crops in India which are often neglected in cropping systems because of lower yield and fluctuating prices. However, pulses have a unique ability to fix atmospheric nitrogen which enhances soil fertility and reduces the need to use synthetic nitrogenous fertilizers. This study has quantified the positive externalities of nitrogen fixation by pulses and its positive impact on farmers' expenses, government subsidies on fertilizers and environment because of reduced production and use of synthetic urea. It has also quantified the amount of monetary support that is needed to bring socially optimal area under pulses. International agencies concerned with environment and climate change should encourage pulse farming as a sustainable way of reducing the emission of global warming gases without affecting farm productivity. Since, pulses are majorly grown by small and marginal farmers under rainfed conditions, any support given to pulses fulfills the equity dimensions of social welfare.

Key words: Pulses, nitrogen fixation, positive externality, greenhouse gases, fertilizer subsidy, urea

JEL Classification: Q18, Q56, Q57

Introduction

Pulses are important source of protein in India but are grown on marginal lands, mostly under rainfed conditions. Farmers give lesser importance to pulse crops because of lower yields and fluctuating prices. Besides, since farmers are not assured of remunerative prices, they shift to other profitable crops or to those crops which have assured procurement. As a result, pulses are often neglected in crop planning. But the inclusion of pulses in farming system brings many benefits. Pulses play an important role in maintaining soil health. They have unique ability to fix atmospheric nitrogen which enhances soil fertility. Besides this, pulses are found to improve soil fertility through physical (such as lowering soil pH) and biological (such as higher beneficial microbial biomass) properties. Studies have also reported improvements in availability of nutrients such as P, K, S, Zn and B in soil because of inclusion of pulses (Singh *et al.,* 2009). Pulses also contribute to soil organic matter in the form of leaf litter. While providing these benefits, the requirement for external inputs by pulses is less. Some of the studies have indicated that pulses use half the non-renewable energy inputs compared to other crops (Zentner *et al*., 2004).

Pulses offer significant health benefits to consumers. Being a cheap source of protein, pulses have particular significance in a predominantly vegetarian country like India. Pulses also play a significant role in reducing malnutrition and enhancing nutritional security. Pulses have low Glycemic Index with fewer calories and more fibres. All these

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distinctive features make pulses a healthy and nutritious food commodity for millions of people in India. The societal benefits of pulses include encouragement to agro industries (dal mills) and consequent employment generation. The pulses have low water footprint compared to other sources of protein. Water footprint per gram of protein in pulses has been found 1.5-times smaller than that in milk, eggs and chicken meat (Mekonnen and Hoekstra, 2010). Moreover, pulses also have lower carbon footprint than other crops (Gan *et al.,* 2011).

Externalities of Pulses Farming

Any action of one economic agent which affects another but is not reflected in market price, leads to a situation which is called an externality. Externality can be either positive (apiculture leading higher pollination in adjacent fields) or negative (pollution affecting quality of life). In case of pulses, cultivation of a pulse crop is a case of positive externality. If a farmer includes pulses in cropping plan and reduces the application of nitrogenous fertilizers in the subsequent crop grown on the same piece of land, he unintendedly helps in saving of government subsidy to be provided for nitrogenous fertilizers. In addition, there is a proportionate reduction in potential environmental damage that might have been caused because of production and use of such synthetic fertilizers. Hence, in this case, Marginal Net Social Benefit (MNSB) from pulses farming is higher than Marginal Net Private Benefit (MNPB) for a farmer as shown in Figure 1. But, a farmer undertakes pulses farming only on the area OQ rather than OQ* (Figure 1) (socially optimum level) because of either lack of awareness or additional support for his environmental services. This results in a welfare loss (benefits forgone because of underproduction) to the entire society (▲ABC). One way of bringing socially optimal level of area under pulse crops and thereby reducing this welfare loss is through providing an additional support to the farmers (PP*) over the market price (OP).

With this background, this study focusses on quantification of positive externalities that can be derived from pulse farming in the form of nitrogen fixation and its positive impact on farmers' expenses, government spending on subsidizing urea price and environment because of reduced production and use of synthetic urea. This study also attempts to arrive at the monetary support that is needed to bring socially optimal level of area under pulses.

Data and Methodology

Nitrogen Fixation

Based on previous studies (Subbarao, 1988; Lee and Wani, 1989; Ali, 1984-87), two commonly reported levels of nitrogen fixation by pulses (40 kg fertilizer

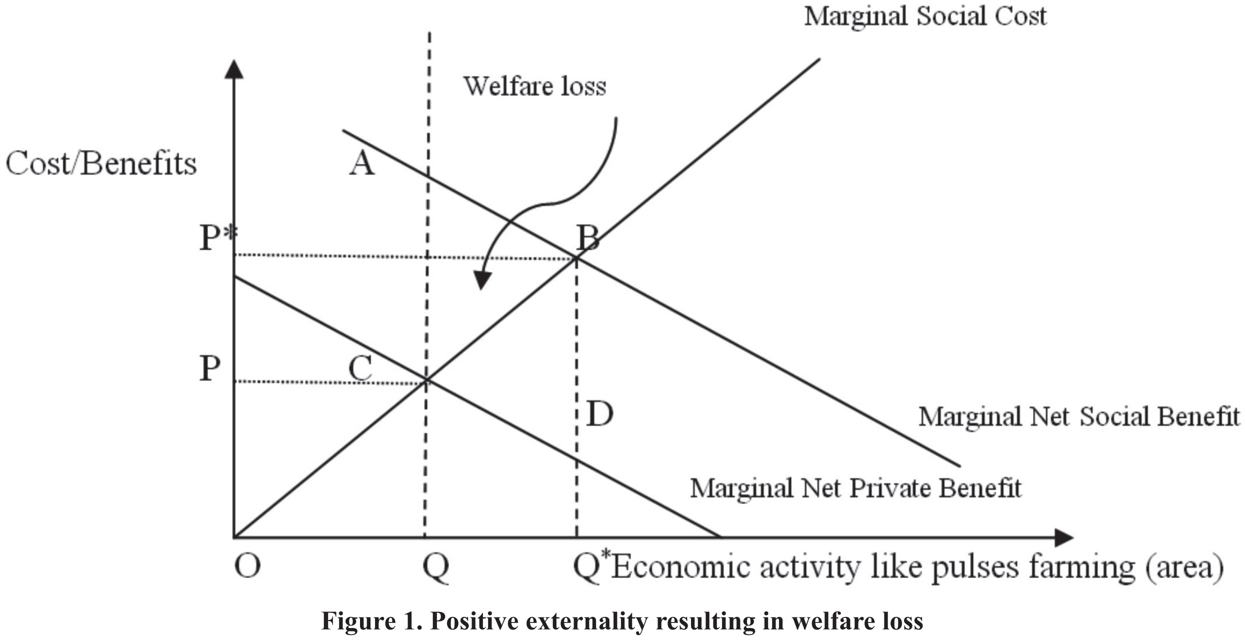

Figure 1. Positive externality resulting in welfare loss

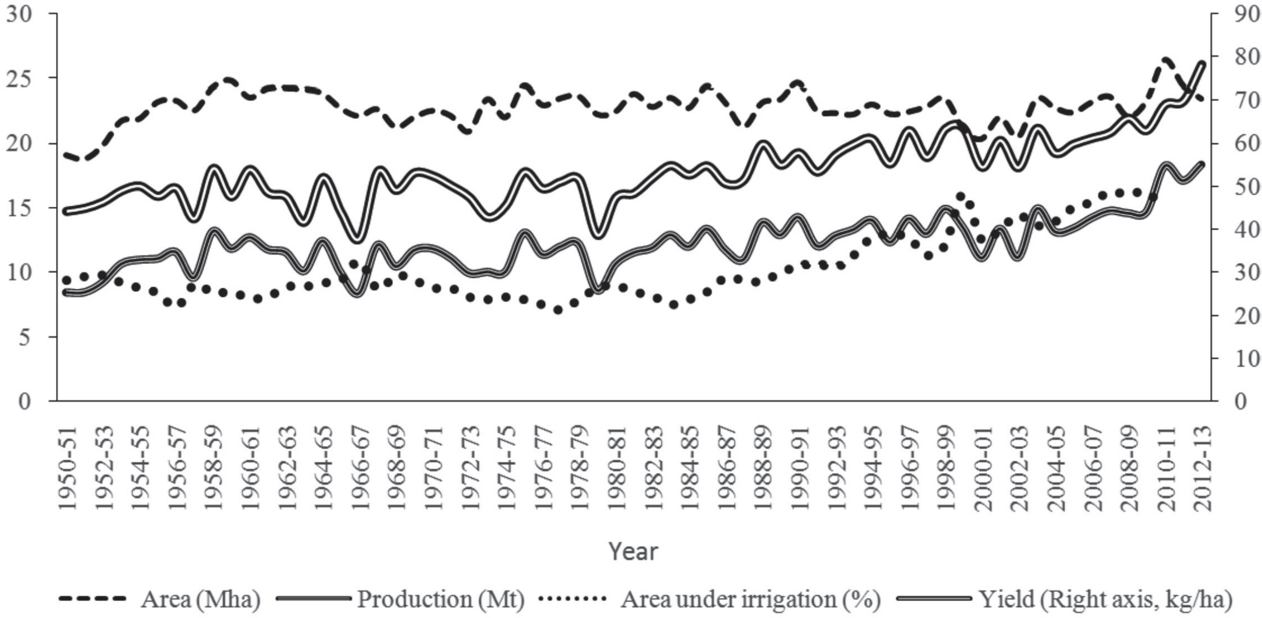

Figure 2. Area, production and yield of pulses in India: 1950-51 to 2012-13

equivalent N/ha and 60 kg N /ha) have been considered for quantification of positive externalities in this study. Using the estimates given in this study, externalities can be worked out for other levels of nitrogen fixation.

Fertilizer Subsidy

Urea being the major nitrogenous fertilizer used in India, has been considered to be the source of synthetic form of nitrogen. Also, the government provides a huge subsidy on urea price to make its availability to farmers at affordable price. To quantify the benefits to farmers, retail price of urea has been used and to measure the saving in subsidies, weighted average (based on the share of domestic production and imports in total usage) of subsidies provided for imported and domestic urea has been considered. The data on usage of urea-use and area, production and productivity of pulses in India have been compiled from the publications of Department of Fertilizers and Ministry of Agriculture, Government of India.

Environmental Benefits

For evaluating the potential environmental benefits by reduced usage and production of synthetic nitrogenous fertilizers, estimates provided by Blottnitz *et al*. (2006) have been used after conversion to Indian Rupees in 2013-14 prices.

Results and Discussion

Production and Price Scenario

India is the largest producer, consumer and importer of pulses in the world. The major pulses grown in India include chickpea (bengalgram/gram), pigeonpea (redgram/arhar/tur), greengram (moong), blackgram (urad) and lentils (masoor). The area, production and yield of pulses over time are presented in Figure 2. Though area and production of pulses have shown a positive trend after 2000, India still needs around 3-4 Mt of pulses to meet their domestic demand. The yield levels in India were around 781 kg/ha for pulses, which were lower than the world average of 904 kg/ha in 2012-13. The area under irrigation has also been less in pulses (14.8 % in 2010-11) than under cereals (56.2 %) and total foodgrains (47.8%).

The cost of production, cost of cultivation, MSP and ruling market prices for major pulses grown in India are presented in Table 1. The minimum support prices were higher for *kharif* pulses, viz. greengram (₹ 4,600/q), pigeonpea and blackgram (₹ 4350/q each) while these were ₹ 3,175/q for chickpea and ₹ 3,075/q for lentil. Though the average market prices during November 2014 were higher than MSP, the range of market prices revealed that there were many instances when the market prices ruled even below the MSP. This shows that without a strong procurement system, the

Table 1. Production cost, cultivation cost, MSP and market prices of major pulses in India

Pulse	Cost of cultivation* (₹/ha)	Cost of production* (₹/quintal)	MSP (₹/quintal)	Average market price# (₹/quintal) (Minimum to maximum)
Pigeonpea	33,963 (US$ 548)	3,234 (US$ 52)	4,350 (US$ 70)	5,075 (3,326 to 7,496)
Greengram	18,143 (US$ 293)	4,296 (US$ 69)	4,600 (US$ 74)	6,845 (4,700 to 8,785)
Blackgram	20,641 (US$ 333)	3,908 (US$ 63)	4,350 (US$ 70)	5,276 (4,281 to 8,079)
Chickpea	28,255 (US$ 456)	2,936 (US$ 47)	3,175 (US$ 51)	3,362 (2,755 to 4,854)
Lentil	20,104 (US$ 324)	2,479 (US$ 40)	3,075 (US$ 50)	4,846 (3,549 to 9,151)

Source: *All India weighted average for the period 2011-12 from DES data
Note: #Average wholesale price (Low to high) Nov, 2014 from http://agmarknet.nic.in/
1 US$= ₹ 62

purpose of MSP gets defeated and farmers are forced to sell their produce in the market at prices lower than MSP or even below the cost of production.

Reduced Fertilizer Costs for Farmers

For agriculture, biological nitrogen (N_2) fixation is a vital natural process (Herridge *et al.,* 2008). Pulses have a unique characteristic of fixing atmospheric nitrogen which reduces the need for nitrogen-based fertilizers. Consequently, there will be proportionate savings in cost incurred on nitrogen fertilizers to the tune of ₹ 466 to ₹ 699 per kg of N per hectare (Table 2). The amount of savings in fertilizers is substantial considering the fact that it excludes other costs associated with transportation and application. The problems of gaseous loss, runoff loss and leaching also arise on application of synthetic fertilizers and these reduce the amount of effective N added to soil from urea below 46 per cent. Other costs such as on transporting urea and labour-use for application of urea in the field do not arise in case biological nitrogen fixation. All these features indicate that biological nitrogen has the potential to substitute the application of urea in terms of both cost and effectiveness.

Reduction in Government Subsidy on Nitrogen Fertilizers

India being not self-sufficient in production of fertilizers, imports around 80 lakh tonnes of urea along with the domestic production of 226 lakh tonnes to meet the farmers' needs (Table 3). The per hectare N-use was 84.54 kg with 33.44 kg of P_2O_5 and 10.36 kg of K_2O amounting to 128.34 kg of total NPK-use (2012-13).

India adopted Nutrient Based Subsidy (NBS) Policy on decontrolled phosphatic (P) and potassic (K) fertilizers with effect from 1 April, 2010 to promote balanced fertilization and to improve agricultural productivity. While all other fertilizers are under NBS,

Table 2. Reduction in expenditure on nitrogen fertilizers by farmers

Variables	Value (₹)
Subsidized retail price of urea in India (₹/tonne)	5360 (US$ 86.45)
Subsidized retail price of N/kg (46% of N in urea)	12 (US$ 0.19)
Value of nitrogen fixed at 40 kg N/ha	466 (US$ 7.52)
Value of nitrogen fixed at 60 kg N/ha	699 (US$ 11.28)

Note: 40 kg N =87 kg urea, 60 kg N =130 kg urea

Table 3. Fertilizer scenario in India

(lakh tonnes)

Year	Domestic production		Import		Sales		Total nitrogenous fertilizers		
	Urea	DAP	Urea	DAP	Urea	DAP	Production	Import	Use
2010-11	218.81	35.37	66.10	76.97	282.10	112.68	121.57	44.93	165.58
2011-12	219.84	39.63	78.34	69.05	293.60	111.88	122.59	52.40	173.00
2012-13	225.75	36.47	80.44	57.02	301.60	92.29	121.94	35.05	168.20

Source: *Indian Fertilizer Scenario 2014*, Ministry of Chemicals and Fertilizers, Government of India, New Delhi

urea is still under statutory control. The price of urea at present is ₹ 5360/tonne (exclusive of taxes). The difference between the delivered cost of fertilizers at farm gate and the price payable by the farmer is reimbursed by the Government of India to the fertilizer manufacturers as subsidy. There has been increase in urea subsidy during the past three years while the subsidy on phosphatic and potassic fertilizers has come down since the inception of NBS scheme during 2010 (Figure 3).

India imports a substantial quantity of urea and imported 7 Mt of urea (25 % of total requirement) in 2013-14 along with production of around 22.72 Mt of urea domestically. While importing urea, the central government not only spends its scarce foreign exchange, but also the amount spent in the form of subsidy on imported urea is higher. While the subsidy given for indigenously produced urea was ₹ 12/kg (₹ 25/kg N), it was ₹ 22/kg (₹ 47/kg N) for imported urea during 2013-14. Figure 4 shows the rate of subsidy provided by the central government during the past five years. The weighted average of subsidy provided by the central government based on the relative share of domestic production and imports were calculated. The results showed that central government spent ₹ 30.53/kg of N as subsidy during 2013-14.

By considering ₹ 30.53/kg N (US$ 0.49/kg N) as subsidy, the biological nitrogen fixation of 40 kg N in soil by pulses means a saving in subsidy for the government to the tune of ₹ 1230/ha (US$ 20/ha) and for 60 kg N, this amounts to a savings of ₹ 1840/ha (US$ 30/ha).

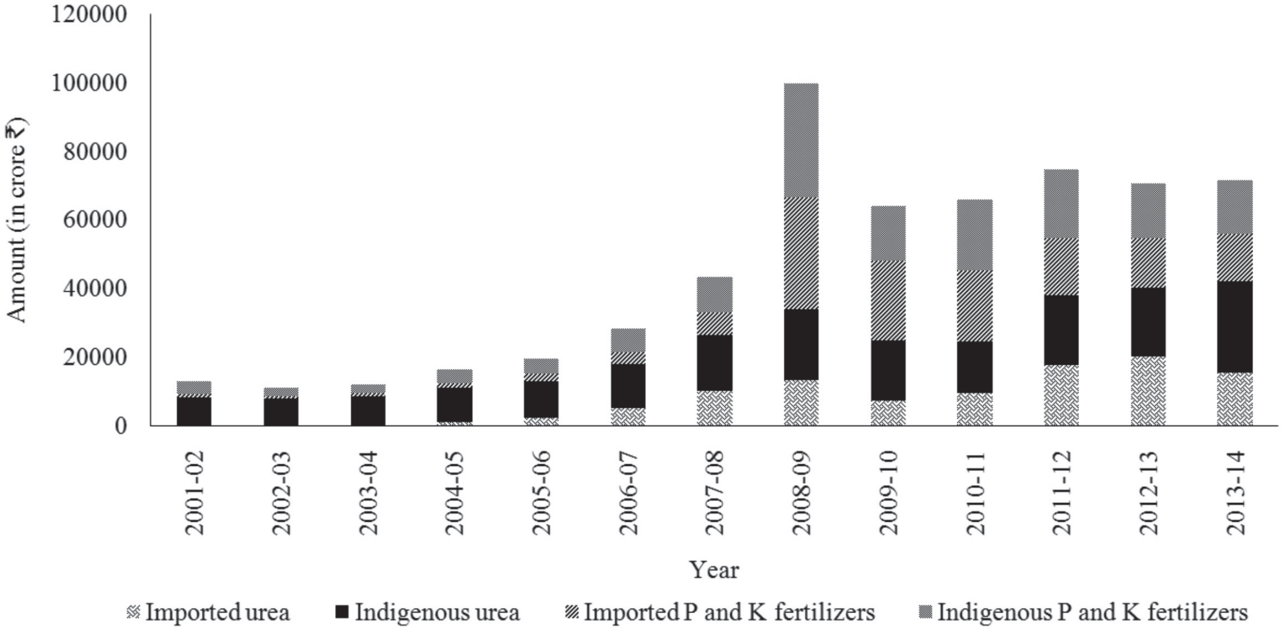

Figure 3. Amount of subsidy paid by Indian government to fertilizer industry

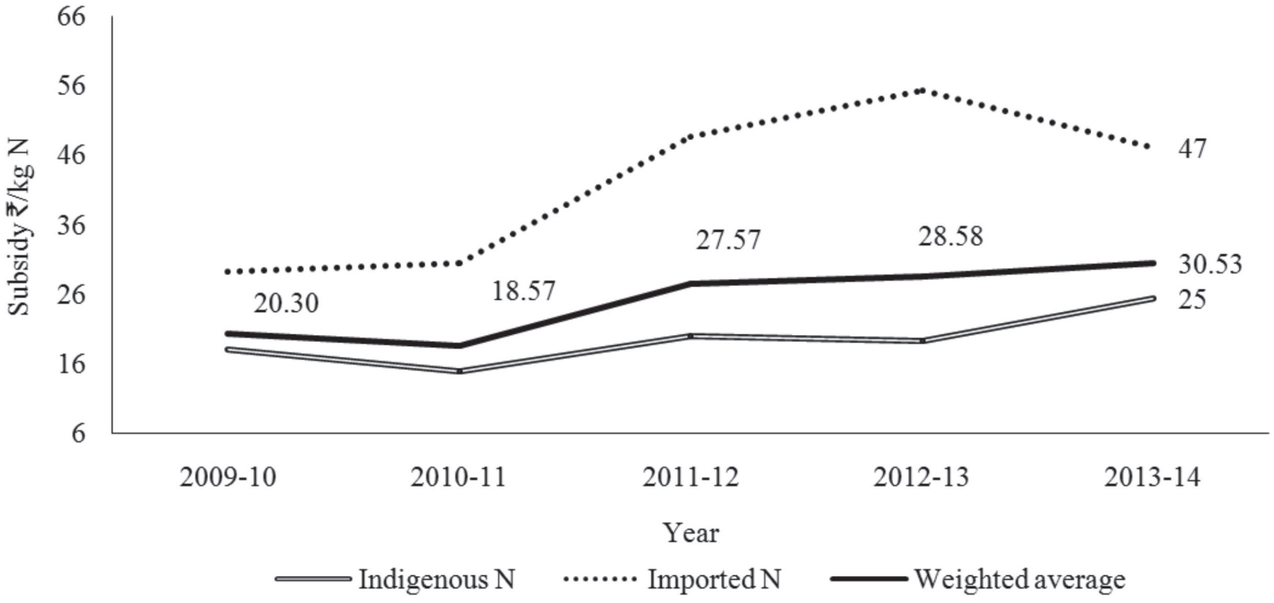

Figure 4. Rate of subsidy (₹ /kg of N) provided by central government: 2009-10 to 2013-14

Environment Damage due to Use of Synthetic Nitrogen Fertilizers and Potential Damage Reduction through Biological Nitrogen Fixation

Biological nitrogen fixation helps in saving the cost on fertilizers for farmers and on subsidies for government. It also helps in minimizing the possible damages to environment during production and use of synthetic nitrogen fertilizers. The potential damages can be in the form of emission of greenhouse gases and air pollutants which affect health and contribute to eutrophication of ecosystems. The production and use of synthetic nitrogen fertilizers also lead to emission of N_2O (nitrous oxide), which is a major ozone layer-depleting gas (Ravishankara *et al*., 2009) and food production (60% of total anthropogenic emissions) is the largest anthropogenic source of nitrous oxide (N_2O) (Syakila and Kroeze, 2011).

In rice-wheat system, from a typical farm field, 0.38 per cent of applied N turns into N_2O (Pathak *et al*., 2002). However, N_2O emissions from biological nitrogen fixation process are much low and are not significant as compared to from other sources (Rochette and Janzen, 2005). Based on these results, Intergovernmental Panel on Climate Change (IPCC, 2006) removed biological nitrogen fixation as a direct source of N_2O emission. This shows that biological nitrogen fixation can substitute the synthetic nitrogenous fertilizers without causing damages to environment. Table 4 shows the estimate of damages to environment that can be saved because of inclusion of pulses in cropping systems. On an average, pulses reduce the environmental damages in terms of emission of greenhouse gases and health effect to the tune of ₹ 1137/ha to ₹ 1705/ha (US$ 18-28/ha).

The estimates of potential benefits from pulses cultivation have been presented in partial budgeting framework in Table 5. To get the realistic representation, pulses growing has been compared with other crop with the assumption of no added cost and reduced return instead of comparing with the land left fallow. Assuming a conservative expenditure on transportation and urea-application in field and 10 per cent application losses, farmers can save ₹ 613-866/ha with inclusion of pulses in the farming system. Further, it would reduce the burden of government subsidy by ₹ 1,221-1,832/ha. After accounting for the reduction in potential damage to environment, the total positive externality of pulses farming was estimated to be ₹ 2,971 to ₹ 4,403/ha (US$ 48-71/ha).

The estimates obtained in the study have been graphically represented under the framework of positive externality in Figure 4. The present level of area under pulses is OQ with market price being OP_1. When farmers are aware of potential benefits, the benefits that they derive increase from OP_1 to OP_2 (an increase by ₹ 613-816/ha). This brings additional area

Table 4. External costs in production and use of synthetic nitrogen fertilizers

Impact category*	€/kgN[*]	₹ /kgN[#]	Reduction in external costs by inclusion of pulses[#]	
			₹ /ha @40kg N	₹ /ha @60kg N
Greenhouse gases from fertilizer production*	0.13	7.01	477	715
NO$_x$ from fertilizer production	0.01	0.54	37	55
NH$_4$NO$_3$ from fertilizer production	0.02	1.08	73	110
N$_2$O from fertilizer in soil	0.12	6.47	440	660
Eutrophication	0.03	1.62	110	165
Health ((infant mortality due to nitrates in drinking water)	Negligible if < 50 mg NO$_3$/L	-	-	-
Total per hectare	0.31	16.71	1137(US$ 18)	1705(US$ 28)

Note: * Estimates provided by Blottnitz *et al*. (2006) were used.
[#] Converted to Indian Rupees using 2005-06 annual average rate: € 1= ₹ 53.91, then converted to 2013-14 prices using conversion factor = WPI 2013-14/WPI 2005-06 = 177.64/104.47=1.7.

Table 5. Estimates of potential benefits from pulses cultivation—Partial budgeting framework

Debit side (A + B)		Credit side (C + D)		
A. Added costs due to inclusion of pulses (₹/ha)		**C. Reduced costs due to inclusion of pulses in farming**		
I. Added cost	0	I. Farmers	₹ /ha @40kg N	₹ /ha @60kg N
		Savings in urea application for next crop	466	699
		Reduction in transportation and labour costs in application of urea	100	120
		Savings in application losses of urea (10%)[*]	47	47
		Total (farmers)	613	866
		II. Government		
		Savings in subsidy	1221	1832
		III. Environment		
		Reduction in potential environment damages due to production and use of synthetic nitrogenous fertilizers	1137	1705
		Sub-total (Governement+Environment)	2358	3537
		Total (Farmers+Governement +Environment)	2971	4403
B. Reduced returns from inclusion of pulses (₹ /ha)		**D. Added returns from inclusion of pulses in farming**		
I. Reduced returns	0	I. Added returns	0	0
		Improvement in soil health • Build-up of soil fertility through soil physical (lower pH) and biological properties (higher microbial biomass) • Improvement in soil organic content and available P, K, S, Zn and B		

Note: * 10 per cent application loss according to Ministry of Chemicals and Fertilizers.
A nominal cost of ₹ 100 and ₹ 120 were assumed to be the costs of transportation and labour-use in urea application for 40 kg N and 60 kg N, respectively.

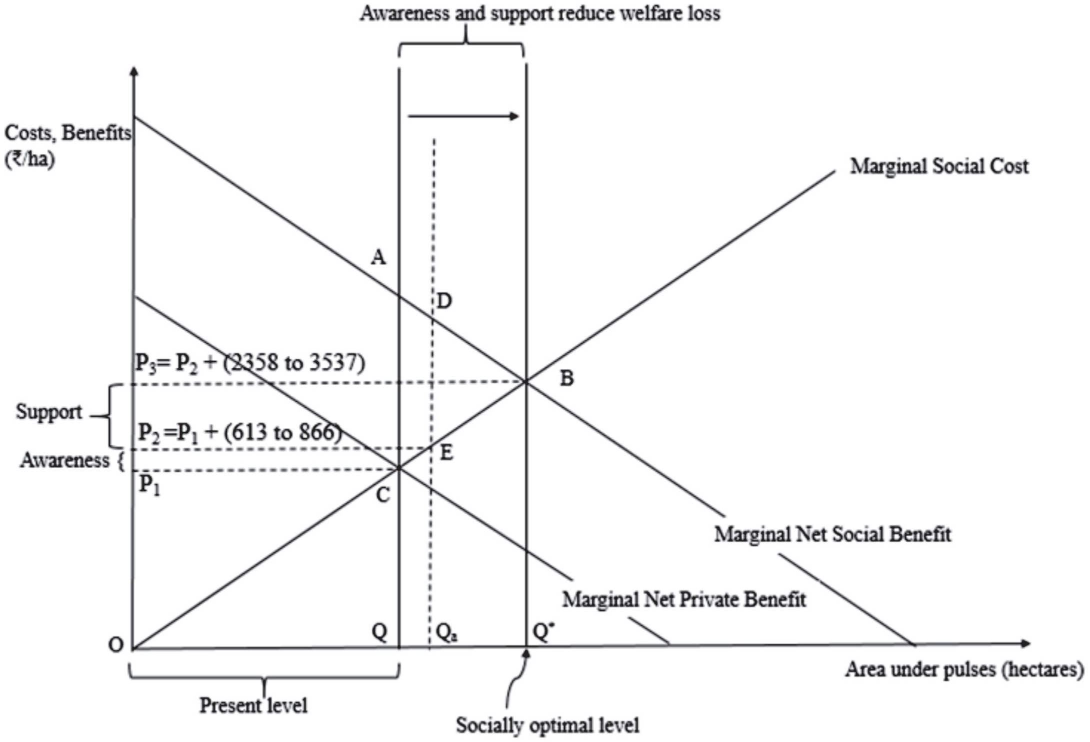

Figure 5. Positive externality in pulse farming in India

under pulses (QQ_a), thereby reducing the quantum of welfare loss from earlier level▲ ABC to ▲DBE. When farmers receive support for saving the governmental subsidy and for their environmental services [OP_3=OP_2+(₹ 2358-3537/ha)], socially optimal level (OQ^*) can be achieved and thereby welfare loss can be reduced to zero. Awareness and support not only bring about additional area but also encourage the farmers to adopt improved farming practices in pulses.

Conclusions and Policy Implications

The study has demonstrated the potential benefits that the farmers can get by inclusion of pulses in their cropping system. The awareness generation regarding nitrogen fixation by pulses can convince the farmers to reduce the usage of nitrogenous fertilizers, which in turn would reduce the burden of subsides on government. To attain socially optimal level of pulses farming, the pulse growers should be provided additional support for their services to environment. Encouragement could be provided in the form of equivalent subsidy on phosphorus fertilizers as application of phosphorus fertilizers in pulses increases nodulation and nitrogen fixation (Shukla and Yadav, 1982). Further, subsidizing phosphorus fertilizer can also help in reducing the imbalance in N:P:K- usage in India (Ideal NPK ratio is 4:2:1 and it was 7.9 : 3.1 : 1 in India in 2013-14). This can help in reducing greenhouse gas emission and preventing other environmental issues associated with synthetic fertilizers like health, eutrophication and pollution. Therefore, international agencies concerned with environment and climate change should encourage pulse farming as a sustainable way of reducing the emission of global warming gases without affecting farm productivity. Since, pulses are majorly grown by small and marginal farmers under rainfed conditions, any support given to pulses fulfills the equity dimensions of social welfare.

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References

Ali, M. (1984-1987) *Annual Report.* Indian Institute of Pulses Research, Kanpur.

Blottnitz, H., Von Rabl, A., Boiadjiev, D., Taylor, T. and Arnold, S. (2006) Damage costs of nitrogen fertilizer in Europe and their internalization. *Journal of Environmental Planning and Management*, **49**(3): 413-433.

Gan, Y., Liang, C., Hamel, C., Cutforth, H. and Wang, H. (2011) Strategies for reducing the carbon footprint of field crops for semiarid areas: A review. *Agronomy for Sustainable Development*, **31**(4): 643-656. Retrieved from https://hal.inria.fr/file/index/docid/930478/filename/hal-00930478.pdf

Herridge, D.F., Peoples, M.B. and Boddey, R.M. (2008) Global inputs of biological nitrogen fixation in agricultural systems. *Plant and Soil*, **311**(1-2): 1-18.

IPCC (2006) *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, *Agriculture, Forestry and other Land Use, N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application*. Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Lee, K.K. and Wani, S.P. (1989) *Proc. Colloquium on Soil Fertility and Fertilizer Management in Semi-Arid and Tropical India*. IFDC Muscle Sholas, AL. pp. 89-108.

Mekonnen M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of farm animals and animal products. *Value of Water Research Report Series No.48.* UNESCO-IHE.

Pathak, H., Bhatia, A., Prasad, Shiv, Singh, S., Kumar, S., Jain, M.C. and Kumar, U. (2002) Emission of nitrous oxide from soil in rice-wheat systems of Indo-Gangetic plains of India. *Journal of Environmental Monitoring and Assessment,* **77**(2): 163-178.

Ravishankara, A.R., Daniel, J.S. and Portmann, R.W. (2009) Nitrous oxide (N_2O): The dominant ozone-depleting substance emitted in the 21st century. *Science*, **326** *(*5949): 123-125. Retrieved from http://ozone.unep.org/Assessment_Panels/Ravishankara%20et%20al_Science_N2O_10_2_09.pdf

Rochette, P. and Janzen, H.H. (2005) Towards a revised coefficient for estimating N_2O emissions from legumes. *Nutrient Cycling in Agroecosystems*, **73**(2-3): 171-179.

Shukla, U.C. and Yadav, O.P. (1982) Effect of phosphorus and zinc on nodulation and nitrogen fixation in chickpea (*Cicer arietinum L.*). *Plant and Soil*, **65**(2): 239-248.

Singh, K.K., Ali, M. and Venkatesh, M.S. (2009) *Pulses in Cropping Systems*. Technical Bulletin, Indian Institute of Pulses Research, Kanpur.

Subbarao, N.S. (1988) *Biological Nitrogen Fixation: Recent Developments*. Oxford and IBH, New Delhi. pp. 1-19.

Syakila, A. and Kroeze, C. (2011) The global nitrous oxide budget revisited. *Greenhouse Gas Measurement and Management*, **1**(1): 17-26. Retrieved from http://www.tandfonline.com/doi/pdf/10.3763/ghgmm.2010.0007

Zentner, R.P., Lafond, G.P., Derksen, D.A., Nagy, C.N., Wall, D.D. and May, W.E. (2004) Effects of tillage method and crop rotation on non-renewable energy use efficiency for a thin Black Chernozem in the Canadian Prairies. *Soil & Tillage Research*, **77**: 125-136.

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