Title : Impact of Shelterbelts on Groundnut Production in Therilands :

A Decomposition Analysis.

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Abstract

In areas characterized by wind erosion and shifting sand dunes, shelterbelts can increase crop yields. Groundnut yields in southern India increased with the introduction and maturation of shelterbelts. Decomposition analysis attributed most of the yield increases to the shelterbelts themselves, with a small portion attributed to input use changes. While shelterbelt cost data are scarce, the estimated value of inputs saved due to shelterbelts suggested a net benefit stream that is initially negative but increasing into the indefinite future. Public investments in shelterbelts may be the most effective means of preventing land degradation.

Background and Objectives

Since 1945, almost 11 per cent of the earth's agricultural land has been moderately or strongly degraded, causing substantial reductions in productivity (Olderman et al., 1990). In a developing country like India, soil erosion and degradation are among the most severe environmental problems. Various forms of soil degradation affect nearly 53 per cent of the total geographical area of the country. Wind and water erosion are the most important causes of land degradation, affecting 141 million hectares of land. Population pressure, intensive cultivation, and lack of conservation strategies contribute to the gradual degradation of land resources. The per capita availability of cultivable land in India declined from 0.48 hectare in 1951 to 0.25 hectare in 1981, and it is expected to decline to 0.15 hectare by 2005 (Government of India, 1994).

In the southern state of Tamil Nadu, 3.82 million hectares, constituting 29 percent of the state's geographical area are affected by soil erosion and other kinds of land degradation. In Tirunelveli and Tuticorin districts, nearly 200,000 hectares are deemed degraded. The eastern parts of the Tirunelveli and Tuticorin districts suffer from wind erosion and moving sand dunes as large areas are kept fallow. These areas are called "theries" or "therilands", and cover 20,171 hectares.

Soil degradation imposes on-farm and off-farm costs. On-farm impacts include declining yield levels, subsequent higher application rates of chemical inputs, shifts in cropping patterns from high to low valued crops, and in extreme cases, abandonment of cultivation. Off-farm costs includes sedimentation of reservoirs and canals, deterioration of water and air quality, and welfare loss from declining farm productivity.

Shelterbelts formed by planting rows of closely spaced trees are a proven wind erosion control technique. Public investment funds most wind erosion control programs in India. The Department of Agricultural Engineering, with funding from the Government of India, first formed shelterbelts in Tamil Nadu's therilands in 1978–79, and are referred to as Phase I in this study. Acacia, cashew and neem trees were planted using intra-row spacing of three meters, inter-row spacing of three meters, and inter-belt spacing of 160 meters. Subsequently, with Danish International Development Agency (DANIDA) assistance, the Department of Agricultural Engineering undertook a Comprehensive Watershed Development Program (CWDP) that included additional shelterbelt formation. Shelterbelts created from 1991 to 1994 are referred to as Phase II in this study. Additional program activities, for which data are not yet available, extend from 1995 to 2004.

The initial wind erosion control project in 1978-79 covered an area of 13,000 hectares in Sathankulam and Tuticorin taluks in Tuticorin district and Radhapuram taluk in Tirunelveli district. Three villages in this area have therilands. Phase II of the CWDP covered an area of 17,000 hectares. Of the 32 revenue villages in this area, 11 villages are located in therilands.

Wind erosion control via shelterbelts potentially offers significant economic benefits in many locations throughout the world. Shelterbelts contributed to yield increases in the Great Plains (Brandle and Marsh, 1995) and Canadian prairies (Timmermans and Casement, 2001), particularly when the trees were mature (Kort and Brandle, 1999; Grala and Colletti, 2001). Net present value analyses in the Great Plains have been mixed. McMartin, *et al*., (1974) found that wheat yield increases were insufficient to compensate for land taken out of production, but Brandle, *et al*., (1984) and Brandle, *et al.,* (1992) found positive net present values for Nebraska wheat over a range of conditions. Outside North America, studies conducted in the Indus Basin of Pakistan showed a doubling of crop production, and income growth of 180 percent due to increased production was reported in Taklimakan, China (UNEP, 1997). Economic evaluations, are rare in desert environments. This study contributes an analysis of primary data from a long-running shelterbelt program in a commercial agricultural setting. As empirical evidence from site-specific, crop-specific applications accumulates, decision makers in similar environments will be better equipped to assess the benefits of shelterbelts.

The overall objective of the study was to determine if shelterbelts induce a statistically and economically significant increase in groundnut productivity in therilands. The analysis addressed groundnut production because it is the predominant crop in the study area, accounting for 34 percent of total crop value. Specific objectives of the study were to:

(i) decompose total changes in groundnut yield into selected components that include shelterbelt status and input use,

(ii) estimate the value of inputs saved in groundnut cultivation with shelterbelts, and

(iii) based on the results, provide recommendations regarding shelterbelt establishment in areas threatened by wind erosion and shifting sand dunes.

While data allow analysis of private benefits, objective (iii) was constrained by limited information on shelterbelt costs. Estimation of public benefits from controlling erosion and desertification was beyond the scope of this study.

Project Design and Data Collection

Tuticorin district was selected as the study area because its therilands contain the largest area protected by shelterbelts under the CWDP. Three villages were selected, one in the Phase I area where the shelterbelts were established in 1978–79, one in the Phase II area where shelterbelts were established in 1991–94, and one in an area not protected by shelterbelts. The villages were chosen to maximize the similarity of production factors other than shelterbelt status. Thirty respondents from each village were randomly selected to participate in the study. Data collection from the sample respondents occurred during January and February 2000, by which time the groundnut harvest was complete.

Primary data were collected from respondents in pre-tested interviews. The purpose of the study was explained to farmers to ensure their co-operation and encourage accurate responses. Primary data included farmers' age, education, land holding, cost and returns of groundnut cultivation, input use, yield, credit availability, and marketing techniques. Secondary data included land use patterns, cropping patterns, irrigation, rainfall, soils, shelterbelts, socio-

economic factors, and infrastructure available in the study area. Secondary data sources included published and unpublished records of the state Department of Agricultural Engineering, the DANIDA project office, the Department of Economics and Statistics, and the Agricultural Research Station in Kovilpatti. Errors in data collection, such as recall bias, were minimized through crosschecks.

Decomposition Analysis, Allocative Efficiency, and Value of Inputs Saved

Determining the differential impact of shelterbelts on yield required a statistical decomposition of factors affecting yield into distinct components. Decomposition techniques have been used in a variety of agricultural applications, including decomposition of crop output levels and growth (Misra, 1971; Tzouvelekas, *et al.*, 1998), output variance (Hazell, 1984), influence of technical change (Cauvery, 1991; Kalirajan et al., 1996), impact of seed variety adoption (Kiresur, 1995), and impacts of policy reforms (Fan, *et al.*, 1997). For the present study, the decomposition model suggested by Bisaliah (1977, 1978) was most appropriate. A production function was first specified by expressing groundnut yield Y as a function of land, labor, fertilizer, and plant protection chemical input quantities.

The log-linear production function explained variance in sample groundnut production better in terms of adjusted R^2 than the quadratic and translog functional forms. The production function was specified on a per hectare basis. Fertilizer price is regulated by the government, so the per unit cost was equal for all farmers. Wages paid on a per day basis were different for men and women; hence the wage rate was rescaled to reflect mandays.

$$\ln Y_1 = \ln A_1 + a_1 \ln L_1 + b_1 \ln F_1 + c_1 \ln P_1 + u_1 \quad (1)$$

$$\ln Y_2 = \ln A_2 + a_2 \ln L_2 + b_2 \ln F_2 + c_2 \ln P_2 + u_2 \quad (2)$$

$$\ln Y_3 = \ln A_3 + a_3 \ln L_3 + b_3 \ln F_3 + c_3 \ln P_3 + u_3 \quad (3)$$

where,

Y = yield (kg/ha.)

L = labor (mandays/ha.)

F = fertilizer (rupees/ha.)

P = plant protection chemicals (rupees/ha.)

A = scale parameter

a, b & c = regression parameters (factor elasticities)

u = random disturbance term.

Equations (1), (2), and (3) represent the production relationship during 1999-2000 in areas without shelterbelts, and in areas where shelterbelts were formed in 1991-94 and 1978-79, respectively.

Algebraic manipulation of (1) and (2) implies :

$$\begin{aligned} \ln Y_2 - \ln Y_1 = {} & (\ln A_2 - \ln A_1) + (a_2 \ln L_2 - a_1 \ln L_1 + a_2 \ln L_1 - \\ & a_2 \ln L_1) + (b_2 \ln F_2 - b_1 \ln F_1 + b_2 \ln F_1 - b_2 \ln F_1) + \\ & (c_2 \ln P_2 - c_1 \ln P_1 + c_2 \ln P_1 - c_2 \ln P_1) + (u_2 - u_1) \end{aligned} \quad (4)$$

Further rearrangement yields :

$$\begin{aligned} \ln (Y_2/Y_1) = {} & \ln (A_2 / A_1) + [(a_2 - a_1) \ln L_1 + (b_2 - b_1) \ln F_1 + \\ & (c_2 - c_1) \ln P_1)] + [(a_2 \ln (L_2/L_1) + b_2 \ln (F_2/ F_1) + \\ & c_2 \ln (P_2/ P_1)] + (u_2 - u_1) \end{aligned} \quad (5)$$

The equation for $\ln(Y_3/Y_1)$ is analogously expressed.

The dependent variable in equation (5) represents the difference in the log of yields between areas with and without shelterbelts. The first bracketed expression is the sum of changes in factor elasticities, each weighted by the log of input quantity used in the control scenario (without shelterbelt). The term is interpreted as change in yield due to changes in factor elasticities. The second bracketed expression is the sum of differences in the log of input quantities between areas with and without shelterbelts each weighted by the input's factors elasticity corresponding to the treatment scenario (with shelterbelts). This term represents change in yield due to changes in the per hectare quantities of labor, fertilizer and plant protection chemicals used.

Allocative efficiency in areas with and without shelterbelts can be evaluated using the production function parameter estimates. Assuming farmers are price takers in input and output markets, the efficiency condition requires a unitary ratio of the value of marginal product (VMP) and factor price (w). Parameter estimates represent factor elasticities (ε), implying that the ratio (VMP_i/w_i) for factor x_i equals $\varepsilon_i Y/x_i$. Statistically significant deviations from unity suggest allocative inefficiency.

The value of inputs saved by planting shelterbelts was estimated by first calculating the value of resources necessary to produce per hectare output observed in the shelterbelt areas using the technical relationship observed in the unprotected area. The difference between this value and the value of inputs actually used in protected lands represents the value of inputs saved due to greater technical efficiency induced by shelterbelts (Schultz, 1953). The following expression allows estimation of the value of inputs saved in areas with shelterbelts:

$$R_{al} = (1 + \gamma / 100) R_{pl}$$

$$S_r = (\gamma / 100) R_{pl} \text{, where} \qquad (6)$$

Y_{pl} = per hectare output in protected land

Y_{al} = per hectare output in unprotected land

R_{pl} = Value of inputs used in producing Y_{pl} on protected land.

R_{al} = Value of inputs required to produce Y_{pl} on unprotected lands

(= Per cent increase in output per hectare in protected lands with the volume of inputs used per ha in affected lands

S_r = Value of inputs saved to produce Y_{pl} with (protection) shelterbelts.

Results

The sample in each of the three study areas (30 observations each) was divided at the median farm size value into two subsamples. The inputs used and yield of groundnut in the sample farms are given in Table 1, seeds and labor account for the major share in the cost of production of groundnut. *F*-values from two-factor ANOVA for the size groups and the three study areas were 2.70 and 24.58 respectively. The tests indicated that farm size did not affect yield, but shelterbelt status did. The joint equality of production function coefficients across shelterbelt regimes was tested via Chow tests. F-values of 200.07 (Phase I vs. unprotected), 213.41 (Phase II vs. unprotected) and 31.23 (Phase I vs. Phase II) indicated significant differences between estimated coefficients (i.e., factor elasticities) in each pair of regression equations.

As shown in Table 2, the estimated production functions explained 60, 40, and 58 percent of yield variation in the Phase I shelterbelt areas, Phase II shelterbelt areas, and unprotected areas, respectively. All statistically significant factor elasticity estimates were positive, as expected. Labor was significant in all three regressions, and was substantially more elastic in unprotected areas (0.45) than in protected areas (0.16 and 0.06). Fertilizer was significant in the

two areas protected by shelterbelts, with factor elasticities of 0.24 and 0.26. Plant protection chemical inputs were significant only in the Phase I area, with the longest period of shelterbelt protection, and the estimate was highly inelastic.

Allocative efficiency tests, shown in Table 3, indicate that consistency with the efficiency condition ($VMP_i/w_i = 1$) was the exception rather than the rule. Labor in areas without shelterbelts appeared to be the only input used in an allocatively efficient quantity. The remaining inputs with significant production function parameter estimates appeared to be either over-utilized (labor) or under-utilized (fertilizer and plant protection chemicals). One might expect such a result in areas characterized by binding input supply and/or liquidity constraints, and few employment opportunities, but the districts in the study area are not known for these features.

Table 4 presents results of the decomposition analysis, suggesting that shelterbelts were the dominant cause of productivity difference of the variables examined. Relative to unprotected areas, Phase I area yields were 20.9 percent higher, and Phase II area yields were 11.8 percent higher. Changes in labor, fertilizer, and plant protection chemical input use accounted for only 3.2 percent and 1.6 percent of the Phase I and Phase II productivity increases, respectively. Of these inputs, increased fertilizer use appeared to be the most influential, consistent with its relatively high factor elasticity. The remaining 17.8 percent and 10.1 percent respective yield increases were attributed to shelterbelts. Shelterbelt productivity gains increased with age, as the shelterbelts provided better protection against shifting sand dunes. The more established Phase I areas enjoyed an 8.8 percent yield advantage over areas containing the more recently established Phase II shelterbelts. Maturation of the shelterbelts contributed a 7.7 percent yield increase, and input use changes accounted for the remaining 1.1 percent increase.

The values of inputs used to produce the average observed yield in Phase I areas and Phase II areas were 9,912 rupees/ha. and 10,214 rupees/ha., respectively. Predicted yields in protected areas, conditional on input levels used in unprotected areas, were 18 percent higher in Phase I areas and 10 percent higher in Phase II areas. Applying these values in equation (6) implies that, relative to unprotected areas, shelterbelts induced input savings valued at 1,784 rupees/ha. in Phase I areas and 1,032 rupees/ha. in Phase II areas. The values of inputs saved represent 17 percent of total costs in Phase I areas, and 10 percent of total costs in Phase II areas. Over the course of 15 years (Phase I versus Phase II), shelterbelt maturation allowed input savings valued at 763 rupees/ha., or 8 percent of total costs.

Conclusions and Policy Implications

The results of this study make a strong argument for shelterbelt establishment in semi-arid areas characterized by wind erosion and shifting sand dunes. Shelterbelts substantially enlarged the production possibilities set and allowed economically significant input savings. With much of the world's arable land declining in productivity, the double-digit percentage gains in yield offered by shelterbelts present an attractive management alternative. Unlike new seed varieties, manufactured chemical inputs, or mechanized equipment, shelterbelts represent a technology that is locally accessible worldwide. Shelterbelts are a flexible technology that can be adapted to diverse conditions via indigenous species selection. Where feasible, fruit and nut trees planted in shelterbelts can themselves yield economic returns.

Data on the capital cost of establishing shelterbelts were not available for this study, but typical maintenance costs in the initial year were estimated at 1,906 rupees/ha. Costs consisted of shelterbelt repair (824 rupees/ha.), new bore-well installation and repair of existing wells (635

rupees/ha.), observation and research trials (64 rupees/ha.), and overhead charges (383 rupees/ha.). Shelterbelts can be essentially permanent structures that require initial investments followed by declining maintenance costs over time, whereas the benefits grow as the trees mature and extend for decades until replanting becomes necessary.

While the data used in this study offered a rare opportunity to assess the private benefits of shelterbelts, additional data on capital costs and the rate of decline in maintenance costs are necessary to make definitive statements about the expected net present value of establishing shelterbelts in similar environments. In cases where capital and initial maintenance costs are paid by governments or international aid organizations, farmers and local economies clearly face incentives to support shelterbelt establishment. Absent outside investment, however, the net benefit trajectory may well appear unattractive, particularly if discount rates are high. The failure to renovate Great Plains shelterbelts established during the Dust Bowl years (Annou and Pederson, 2000) suggests this is often the case.

Shelterbelts appear to induce sufficient productivity gains in environments featuring wind erosion and moving sand dunes to warrant serious consideration as public investments. Expected net present value including private and public net benefits remains to be quantified, but current trends in land degradation, desertification, and population growth suggest an increasing opportunity cost of failing to pursue strategies such as shelterbelts.

REFERENCES CITED

Annou, M. and G. Pederson. Spring, 2000. "The Economics of Windbreak Renovation." *Agricultural Economics Newsletter*, University of Minnesota Extension Service.

Bisaliah, S. 1978. "Decomposition Analysis of Employment Change Under New Production Technology in Punjab Agriculture." *Indian Journal of Agricultural Economics*. 33,2:70-80.

Bisaliah, S. 1977. "Decomposition Analysis of Output Change Under New Production Technology in Wheat Farming." *Indian Journal of Agricultural Economics*. 23,3: 193 – 201.

Brandle, J.R., B.B. Johnson, and T. Akeson. 1992. "Field Windbreaks: Are They Economical?" *Journal of Production Agriculture*. 5:393-398.

Brandle, J.R., B.B. Johnson, and D.D. Dearmont. 1984. "Windbreak Economics: The Case of Winter Wheat Production in Eastern Nebraska." *Journal of Soil and Water Conservation*. 39,5:339-343.

Brandle, J.R. and M. Marsh. 1995. "The Economic Impact of Field Shelterbelts in the Northern Great Plains." Proceedings of the Fourth North American Agroforestry Conference. Idaho, July 23-28.

Cauvery, R. 1991. "Groundnut Production in Tamil Nadu – A Decomposition Analysis." *Agricultural Situation in India***.** 46,5:321–324.

Fan, S., E.J. Wailes and K.B. Young. 1997. " Policy Reforms and Technological Change in Egyptian Rice Production: A Frontier Production Function Approach." *Journal of African Economics.* 6,3:391–411.

Government of India. 1994. "Indian Agriculture in Brief." (25 ed.), Directorate of Economics and Statistics, Department of Agriculture and Co-operation. 22, 25.

Grala, R. and J. Colletti. 2001. "Summary of the Shelterbelt Economic Analysis." posted on www.forestry.iastate.edu/res/Economics.html.

Hazell. P.B.R, 1984. "Sources of Increased Instability in Indian and US Cereal Production." *American Journal of Agricultural Economics*. 66,3:302–311.

Kalirajan, K.P, M.B. Obwona and S. Zhao. 1996. "A Decomposition of TFPG: The Case of Chinese Agricultural Growth Before and After Reforms." *American Journal of Agricultural Economics*. 78,2:331–338.

Kiresur. 1995. "Technological Change in Sorghum Production: An Economic Study of Dharwad Farms in Karnataka." *Indian Journal of Agricultural Economics*. 50,2:185–192.

Kort, J. and J.R. Brandle. 1999. "The Economics of Shelterbelts." Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, posted on www.agr.ca/pfra/shbpub/shbpub61.htm.

McMartin, W., A.B. Frank, and R.H. Heintz. 1974. "Economics of Shelterbelt Influence on Wheat Yields in North Dakota." *Journal of Soil and Water Conservation*. 29,2:87-91.

Misra, V.N. 1971. "Growth of Crop Output in Gujarat: A Component Analysis." *Anvesak*. 1,1.

Olderman, L.K, R.T.A. Hakkeling and W.G. Sombroek. 1990. "World Map of the Status of Human-Induced Soil Degradation: An Explanatory Note, 2nd ed." Wageningen, Netherlands: International Soil Reference and Information Centre.

Schultz, T.W. 1953. *Economic Organization of Agriculture*. New York: McGraw Hill.

Timmermans, J. and B. Casement. 2001. "Field Shelterbelts for Soil Conservation." posted on www.agric.gov.ab.ca/agdex.

Tzouvelekas, V., K. Giannakas, and G. Karaqiannis. 1998. "Efficiency, Productivity and Output Growth: An Inter-Regional Analysis of Greek Agriculture." Presented at the annual meetings of the American Agricultural Economics Association, Salt Lake City, Utah, August 3 – 5.

UNEP (United Nations Environment Programme). 1997. "Success Stories of 1995." posted on http://www.unep.org/unep/program/natres/land/sucess95.htm.

Table 1. Mean Factor Use and Groundnut Yield by Level of Shelterbelt Protection

	Phase I (n= 30)		Phase II (n= 30)		Without Shelterbelts (n= 30)	
	Quantity kg/ha	Value rs/ha	Quantity kg/ha	Value rs/ha	Quantity kg/ha	Value rs/ha
Seeds	116.42	3260	124.82	3495	122.50	3430
Labor (mandays)	112	5600	116	5800	118	5900
Fertiliser						
(i) Nitrogen	17.15	241.09	18.72	253.24	25.74	332.99
(ii) Phosphorus	43.83	616.18	47.85	607.31	40.21	584.47
(iii) Potassium	31.38	169.98	36.00	195.00	41.42	224.36
(iv) Gypsum	347.78	260.84	327.90	245.93	342.43	256.82
Plant protection chemicals	-	157.89	-	191.95	-	223.65
Cost		10305.98		10788.43		10952.29
Yield (pods)	1410.48	17977.50	1290.15	16449.40	1135.93	14483.10

Table 2. Log-linear Production Function Estimates

	Dependent variable: ln(yield)		
	Phase I	Phase II	Without shelterbelts
Constant	4.0856**	4.3935**	4.8938**
	(0.7474)[a]	(0.8370)	(0.7730)
Labor (Mandays)	0.1642**	0.0604*	0.4536**
	(0.0608)	(0.0269)	(0.0935)
Fertiliser (Rs)	0.2431*	0.2636*	-0.1030
	(0.1152)	(0.1312)	(0.1553)
Plant protection chemicals (Rs)	0.0224**	0.0005	0.0287
	(0.0050)	(0.0031)	(0.0149)
R^2	0.60	0.40	0.58

* and ** denote statistical significance at the .05 and .01 levels, respectively.
[a] standard errors in parentheses

Table 3. Value of Marginal Product and Factor Price Ratio (VMP_i / W_i)

	Phase I	Phase II	Without shelterbelts
Labor	0.526**	0.171**	1.11
Fertilizer	3.390**	3.330**	--
Plant protection chemicals	2.550**	--	--

* and ** denote significantly non-unitary values at the .05 and .01 levels, respectively

Table 4. Decomposition of Productivity Differences

Sources of Difference	PhaseI – WS[a]	Percent Phase II – WS	Phase I – Phase II
Total observed change in productivity	21.650	12.730	8.920
Due to Shelterbelts	17.770	10.100	7.660
Due to difference in input use level			
(a) Labor	0.771	0.076	0.566
(b) Fertilizer	1.616	1.625	0.113
(c) Plant protection chemicals	0.766	0.002	0.430
Total estimated difference in productivity	20.923	11.803	8.769

[a] WS denotes area "without shelterbelts"