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Area Supply Response to Other Field Crops with Uncertain Prices and Yields: The Case of Chilli

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ABSTRACT. The research addressed other field crop area supply response at farm level, to examine whether productivity and product price uncertainties which manifest as uncertain profits are of significance in the diversification of paddy based agriculture. An area supply model for a paddy and chilli crop system has been developed within a multi-crop framework, assuming that farmers maximize the expected utility of a multi-attribute utility function having wealth at the end of the season and household rice requirement as the arguments. The model has been estimated using Two Stage Least Squares employing data collected from a cross section of farm households from Hambantota, Matale, Kurunegala and Anuradhapura districts and cover 95/96 Maha and 1996 Yala seasons. The estimates indicate that farmers are unlikely to be risk averse in Maha but in the Yala own profit risk is likely to be of significance in area supply. Tests for the nature of risk aversion indicates that in all except Maha season chilli cultivation neither income transfers to farmers nor taxes/subsidies could effect changes in area supply. The simulation demonstrate the profit risk reducing and mean increasing effects of floor prices and the importance of cross commodity effects in the formulation of price support programs. The results demonstrate the importance of viewing the diversification issue in relation to the paddy base and imply that agricultural policy should concentrate on intensification of paddy production through increasing productivity which will allow farmers to meet household rice needs by concentrating on a lesser paddy area. Farmers relieved of the burden of cultivating paddy extensively, would be in a position to supply more land to OFCs.

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INTRODUCTION

The problem

The research presented in this paper addressed other field crop (OFC) area supply response at farm level, to examine whether productivity and product price uncertainties which manifest as uncertain profits are decisive factors in the diversification of paddy based agriculture. The study focussed on a paddy-chilli crop system, which is representative of diversification of paddy based agriculture in Sri Lanka. The research was motivated by the observations made by researchers that, despite the higher income potential of OFCs compared to paddy at both national and farm levels [World Bank (1993, 1996); Weerahewa and Abeygunawardane (1990)], higher employment opportunities [Samad (1990); World Bank (1996)], a reasonable potential demand; [Dunham (1992, 1993); IIMI (1994)], increasing real prices Dunham (1992, 1993), trade protection [Abeyratne *et al.*, 1991; World Bank (1995)], favorable technical possibilities [IIMI (1991, 1994, 1996); World Bank (1990); Dimantha (1987); Mirando (1989)]; and in the absence of regulatory constraints (Department of Agrarian Services, 1991), the share of land diverted to OFC has been low [Ministry of Agriculture Lands and Forestry (1995); IIMI (1988, 1994); World Bank (1993, 1996)]. The slowness of diversification of paddy based agriculture has been attributed to several reasons. At national level, the government supports to paddy geared to maintain self sufficiency (Kotagama, 1992), low emphasis on other field crop research (World Bank, 1990), and at farm level farmers bias towards paddy production because of the farmers priority to secure family food needs (Heselberg, 1986) have been identified to be some inhibiting factors. It is noted that farmers are faced with problems such as high variations in product prices and productivity, and that majority of Sri Lankan farmers yet see OFC cultivation as a gamble, and suggests the possibility that farmers may be averse to the risk in net returns, thus inhibiting diversification [Panabokke (1989); IIMI (1994, 1996)]. In view of the observed variability in productivity and product prices of other field crops it was considered important to examine whether profit risks are decisive factors in other field crop area supply. If uncertainties in productivity and product prices resulting in risky returns does in-fact have a significant influence on farmers area supply, taking account of this should be essential in the formulation of agricultural policy.

Objectives

The objectives of the research presented here are to examine the significance of risk, nature of risk aversion, and the significance of profit expectations, access to land and irrigation, household rice requirement, household wealth in farm level area supply in a paddy-chilli crop system, through the estimation of econometric models for farm level area supply in a multiple-crop situation, and, to simulate the impact of a price support program on area supply response.

MATERIALS AND METHODS

The model

Literature notes that in semi-subsistence agriculture crop production primarily aims at meeting the domestic food supply from the farm produce and producing a marketable surplus which will help generate an income to the household (Wolgin, 1975; Herath, 1980; Vithanage, 1982; Chavas and Holt, 1990). The area supply model employed in this study has been developed within a multi-crop framework, based on the behavioral postulate that farmers maximize the expected utility of a multi-attribute utility function (Chavas and Pope, 1985) having final wealth from crop production (wealth at the end of the season) and household consumption level of paddy as the arguments. The model is based on the works of Chavas and Holt (1990). The model supposes a farm household producing n crops, consisting of a crop mainly cultivated for food but a surplus is marketed, and cash crops. This model typifies the paddy based agriculture in Sri Lanka, where paddy is cultivated for both household consumption and for the market, and other field crops are cultivated mainly for the market. Suppose C^{0}_{t} is the household consumption level of paddy and π is the net profit from paddy and other field crop production. Under conditions where prices and yields are uncertain to the farmer at the time of making the area supply decision, the net profits (π) is an uncertain variable. Suppose the households preferences are represented by a Von-Neuman-Morgenstern utility function U(..) having final wealth Y and household consumption level of paddy C^{0}_{t} as arguments. Following Chavas and Holt (1990), final wealth (Y) of the farm household at the end of a crop season is defined as the sum of initial wealth of the household (W) and net profits from field crop production (π); initial wealth is proxied by all other net receipts to the household in the crop season, from other agricultural and non agricultural activities not included in π. Thus in this model, the final wealth would be the net income from all other sources as described above, plus, profits from the field crops focused in the model. Under price and yield uncertainties Y is a random variable and therefore the utility function $U(Y, C^0_l)$ itself is a random variable and hence it is postulated that farmers make their land allocation decisions so that their expected utility is maximized subject to constraints on lowland (A_l) and highland (A_h). The optimization problem result in the set of supply response equations for the h th household given by Equation (1),

$$A_{ih} = a_i + \alpha_i \left[W_h + \sum_{j=1}^{n} A_{jh} \bar{\pi}_{jh} \right] \sum_{j=1}^{n} \beta_{ij} \bar{\pi}_{jh} + \sum_{k \geq j}^{n} \sum_{j=1}^{n} \gamma_{ijk} \sigma_{ikh} + \lambda_i C^0_{lh} + \delta_i A_l + \zeta_i A_h + K_i I_h + u_{ih} \qquad (1)$$

The variable A_{ih} is the amount of land the h th household will plant to the i th crop and for $i = 1,..,n$, A_{ih} are simultaneously determined by the system. A_{ih} and hence $W_h + \Sigma A_{jh}\ \pi_{jh}$ are endogenous variables in the model; W_h is the initial wealth of the h th household proxied by the anticipated income to the h th household from all other sources in the cultivation season. The exogenous variables in the model are: $\bar{\pi}_{ih}$ is the h th households expected profits per acre from the i th crop in the current cultivation season. σ_{ijh} are the variance and co-variances of per acre profits from the i th and j th crops of the h th household. C^0_{lh} is the paddy retained for the h th household consumption proxied in the model by the household size. A_{hh} and A_{lh} are the high and low land extent available to the h th household for cultivation of crops $i = 1,..,n$. I is a dummy variable indicating the type of irrigation, differentiating the dependence of field crop cultivation on rain or irrigated water. The model accommodates the postulates that field crop area supply with respect to a group of alternative crops are simultaneously determined and that each depends on the farmers' expectations of net profit from each crop, the net profit risks, anticipated income at the end of the season, level of household rice requirement, availability of high and low land and type of irrigation.

Method of estimation

The Model has been estimated using Two Stage Least Squares (2SLS) estimation technique (Judge *et al.*, 1988) employing data collected from a cross section of 160 farm households spread across 16 villages in Hambantota, Matale, Kurunegala and Anuradhapura districts. The 95/96 *Maha* season and the 1996 *Yala* season were covered by the study. In the estimation of the model it is assumed that the Guaranteed Price Scheme on paddy as well as the Floor Price Schemes on OFCs are both ineffective (ILO, 1986), and hence output prices are untruncated. The EUM hypothesis imply symmetry restrictions on the coefficients of the expected profits (Chavas and Holt, 1990). Hypothesis tests of these restrictions were accepted in all equations and hence the models were estimated with cross equation restrictions imposed.

RESULTS AND DISCUSSION

A summary of the model estimates are presented in Table 1. In both *Maha* and *Yala* the estimates of the paddy-chilli equation system revealed that the availability of lowland, access to irrigation and household size (which was used as a proxy for household consumption level of paddy) are the main factors effecting area supply to paddy. In the *Maha* season paddy equation, insignificance of paddy profit expectations or paddy profit variance indicates that wherever irrigation and lowlands are available farmers seem unconcerned about profit expectations or profit risks of paddy. In the *Maha* season chilli area supply equation, chilli profit expectations and final wealth appear significant. This indicates that in *Maha* where paddy cultivation is dominant, unless with high expected returns farmers are unlikely to consider another field crop. Significance of final wealth could be possibly because chilli is a high cost crop. In the *Yala* season in both paddy and chilli equations, the significance of own profit variances indicates that given the limited availability of water, profit risk of the crop is likely to be important in area supply to the crop. The insignificance of the final wealth in the paddy equations in both seasons indicates that final wealth is not an important consideration in area supply to paddy. Further because final wealth is the endogenous variable that links the paddy and chilli equations in the model, its insignificance implies that, in both seasons, paddy area supply is independent of chilli area supply. But in *Maha* the presence of the final wealth variable in the chilli equation implies that although paddy area supply is independent of chilli area supply, chilli area supply is dependent on paddy area supply. In *Yala*, the insignificance of the final wealth variable in both paddy and chilli equations implies that area supply to the crops are likely to be independent of each other.

Table 1. Summary of Two Stage Square estimates of models.

Model	Equation	R Squared	Variables significant at 90% level of confidence	Inconsistencies with a prior expected signs of coefficients
Maha season	Paddy	0.95	intercept household size lowland irrigation	None
	Chilli	0.96	expected chilli profit final wealth	None
Yala season	Paddy	0.81	intercept household size lowland irrigation variance of paddy profit	None
	Chilli	0.90	intercept variance of chilli profit	None

Note: Household size has been used as proxy for rice requirement of the household.

Hypothesis tests were done to examine the significance of over all risk aversion and the influence of changes in initial wealth and profits on risk aversion and on area supply. Three classes of risk aversion: Decreasing Absolute Risk Aversion (DARA), Constant Relative Risk Aversion (CRRA) and Constant Partial Relative Risk Aversion (CPRRA) (Pope, 1988; Chavas and Holt, 1990; Pope and Just, 1991) were examined. These three classes examine respectively the effects of absolute changes in the initial wealth, proportional changes in initial wealth and profit, on risk aversion and hence on area supply. The test results are presented in Table 2. In both seasons, for

Table 2. Results of the hypothesis tests for risk aversion.

Model	Equation	Computed t or F-test statistic	Degrees of freedom	Critical t or F-value at 90% level of confidence	Test decision
Test for Risk Aversion					
Maha season model	Paddy	0.30	(2, 303)	2.30	Risk neutral
	Chilli	0.39	(2, 303)	2.30	Risk neutral
Yala season model	Paddy	1.14	(2, 223)	2.33	Risk neutral
	Chilli	1.42	(2, 223)	2.33	Risk neutral
Test for Decreasing Absolute Risk Aversion (DARA)					
Maha season model	Paddy	0.26	151	1.30	DARA rejected
	Chilli	2.20	151	1.30	DARA accepted
Yala season model	Paddy	0.52	111	1.29	DARA rejected
	Chilli	0.93	111	1.29	DARA rejected
Test for Constant Relative Risk Aversion (CRRA)					
Maha season model	Paddy	0.02	(1, 303)	2.71	CRRA rejected
	Chilli	0.02	(1, 303)	2.71	CRRA rejected
Yala season model	Paddy	0.10	(1, 223)	2.73	CRRA rejected
	Chilli	0.10	(1, 223)	2.73	CRRA rejected
Test for Constant Partial Relative Risk Aversion (CPRRA)					
Maha season model	Paddy	0.01	(1, 303)	2.71	CPRRA rejected
	Chilli	0.44	(1, 303)	2.71	CPRRA rejected
Yala season model	Paddy	0.01	(1, 223)	2.73	CPRRA rejected
	Chilli	0.39	(1, 223)	2.73	CPRRA rejected

Note: t test used to test for DARA. F test used for others.

both paddy and chilli, the hypothesis of risk aversion, that over all profit variances are significant in area supply is unsupported. This result seem to be in conflict with the observation that in *Yala* season for both paddy and chilli, own profit risks are significant in area supply to the crops, but the traditional testing of risk aversion focus on the null hypothesis that all profit variances are simultaneously zero. Therefore to the extent this study is concerned it is proposed that we conclude that farmers are risk averse with respect to a particular crop area supply, if, at least the own profit is significant. Decreasing absolute risk aversion is refuted in all cases except in *Maha* chilli area supply. The indication is that with the exception of *Maha* season chilli cultivation, absolute changes in initial wealth does not affect risk aversion and hence transfers of wealth to farmers are unlikely to effect area supply to these crops. DARA in *Maha* chilli cultivation is not in conflict with the observation that *Maha* chilli cultivators are not risk averse, because, in any economic activity which involves risky returns, risk aversion of some degree is present although it may not be statistically significant. All cases refuted the hypotheses of constant relative risk aversion and constant partial relative risk aversion implying that proportional changes in initial wealth or profits would have no effect on risk aversion and hence on area supply.

The area supply elasticities are given in Table 3. In the context of the problem, profit elasticity gives the percentage change in area supplied to a crop by a farm household in response to a one percent increase in profit expectations from the crop; the price elasticity, here, gives the percentage change in area supplied to a crop by a farm household in response to a one per cent increase in expected per unit price of the crop. The magnitudes of the elasticity estimates are small and hence unlikely to be appreciably elastic. However, the estimates indicate that chilli supply is more price/profit responsive in *Maha* but paddy is more price/profit responsive in *Yala*. The patterns in the elasticities are possibly because, in the *Maha* season when water is available, an increase in price/profit plays a minor role as farmers already allocate a substantive portion of land to paddy; but for chilli an increase in price/profit will make some increase in area supply. In the *Yala* season where water is scares the impact of an increase in own price/profit on paddy is likely to be higher than in chilli. Likewise the risk elasticities as well as wealth elasticities are small in magnitude but plausible. The risk elasticity gives the percentage change in area supplied to a crop by a farm household in response to a one per cent increase in the variance of profit from the crop. The wealth elasticity gives the percentage change in area supplied to a crop by a farm household in response to a one per cent increase in initial wealth of the household. The risk elasticities indicates that, because farmers are less averse to own profit risks in paddy than to that of chilli the risk elasticities of paddy are lower to those for chilli. Between seasons, elasticities for *Yala* are higher as limitations in water makes farmers more responsive to increases in profit risks. In the case of initial wealth elasticity of area supply in both *Maha* and *Yala* seasons wealth elasticities of chilli are larger. Initial wealth plays a relatively minor role in paddy area supply, but chilli being a high cost crop an increase in initial wealth, is likely to make an increase in area supply to chilli. Although comparable elasticity estimates are unavailable in the literature, the magnitudes of the elasticities as well as the patterns appear plausible.

Table 3. Estimates of area supply elasticities.

Elasticity	*Maha* season model	*Yala* season model
Own profit elasticity of paddy	0.07	0.55
Own profit elasticity of chilli	0.44	0.45
Chilli profit elasticity of paddy	-0.04	-0.20
Paddy profit elasticity of chilli	-0.07	-0.07
Own price elasticity of paddy	0.18	1.15
Own price elasticity of chilli	0.99	0.74
Chilli price elasticity of paddy	-0.09	-0.33
Paddy price elasticity of chilli	-0.16	-0.14
Risk elasticity of paddy	-0.02	-0.12
Risk elasticity of chilli	-0.17	-0.19
Initial wealth elasticity of paddy	0.06	0.10
Initial wealth elasticity of chilli	0.50	0.18

The influence of a price support program on area response was simulated focusing on a floor price program. The truncation of a price caused by a floor on price, results in a truncation of the probability distribution of that price thus influencing both expectation and variance of the price distribution and hence of profits. Therefore simulating the supply response model at different floor price levels allowed examining the impact of alternative floor price levels on the allocation of land to the crops. The simulated effects at various floor price levels are presented in Tables 4 and 5. The simulations revealed that, as expected theoretically, a floor price above the expected output price increases the profit expectation (mean) and reduces the risk (variance). A salient feature revealed by the simulation is the dependence of

Table 4. Simulation of the effects of floor prices on the mean and variance of the paddy and chilli profit distributions.

	Expected price	Floor Price levels						
		+2%	+4%	+6%	+8%	+10%	+15%	+20%
Maha season								
Paddy price Rs/Kg	6.97	7.11	7.25	7.39	7.53	7.67	8.02	8.36
Mean of paddy profit distribution	4.54	5.64	5.76	5.90	6.05	6.2	6.60	7.13
Variance of paddy profit distribution	9.08	2.00	1.12	1.05	0.98	0.91	0.74	0.60
Chilli price Rs/Kg	91.30	93.14	94.96	96.79	98.61	100.44	105.01	109.57
Mean of chilli profit distribution	12.46	16.96	17.28	17.62	18.01	18.42	19.57	20.83
Variance of chilli profit distribution	132.70	12.37	11.59	10.83	10.09	9.39	7.86	6.58
Yala season								
Paddy price Rs/Kg	7.84	8.00	8.15	8.31	8.47	8.62	9.02	9.41
Mean of paddy profit distribution	5.68	6.59	5.69	6.81	6.94	7.08	7.50	7.98
Variance of paddy profit distribution	16.50	2.07	1.94	1.84	1.74	1.64	1.39	1.17
Chilli price Rs/Kg	85.50	87.20	89.00	90.20	92.40	94.08	98.36	102.60
Mean of chilli profit distribution	16.14	16.72	17.07	17.45	17.85	18.27	19.42	20.92
Variance of chilli profit distribution	162.40	92.78	91.99	91.24	90.53	89.85	88.32	83.15

Note: Units of mean (Rs/Acre × 1000), units of variance (Rs/Acre × 1000)

Table 5. Simulation of the effects of floor prices on mean area* of paddy and chilli.

	Maha Season							
	Expected price	Floor price level						
Paddy price (Rs/Kg)	6.97	7.11	7.25	7.39	7.53	7.67	8.02	8.36
Chilli price (Rs/Kg)	91.30	93.14	94.96	96.79	98.61	100.44	105.01	109.57
Effect on area with a floor price on chilli								
Irrigated paddy area	1.29	1.10	1.10	1.09	1.08	1.07	1.04	1.01
Irrigated chilli area	0.30	0.50	0.50	0.51	0.52	0.52	0.54	0.56
Rainfed paddy area	0.97	0.78	0.78	0.77	0.76	0.75	0.72	0.69
Rainfed chilli area	0.23	0.42	0.42	0.43	0.44	0.44	0.46	0.48
Effect on area with a floor price on paddy								
Irrigated paddy area	1.29	1.35	1.35	1.36	1.36	1.37	1.38	1.39
Irrigated chilli area	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Rainfed paddy area	0.97	1.03	1.03	1.04	1.04	1.05	1.06	1.07
Rainfed chilli area	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Effect on area with a floor price on paddy and chilli								
Irrigated paddy area	1.29	1.16	1.16	1.15	1.14	1.14	1.12	1.10
Irrigated chilli area	0.30	0.50	0.51	0.51	0.52	0.53	0.54	0.56
Rainfed paddy area	0.97	0.84	0.84	0.83	0.82	0.82	0.80	0.78
Rainfed chilli area	0.23	0.42	0.42	0.43	0.43	0.44	0.45	0.47

Note: * Mean acreage per farm household

Table 5. Continued.

	Yala Season							
	Expected price	Floor price level						
Paddy price (Rs/Kg)	7.84	8.00	8.15	8.31	8.47	8.62	9.02	9.41
Chilli price (Rs/Kg)	85.50	87.24	88.95	90.18	92.37	94.08	98.36	102.64
Effect on area with a floor price on chilli								
Irrigated paddy area	0.86	0.80	0.79	0.78	0.77	0.76	0.74	0.70
Irrigated chilli area	0.28	0.29	0.29	0.30	0.30	0.30	0.31	0.33
Rainfed paddy area	0.09	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Rainfed chilli area	0.24	0.25	0.26	0.26	0.26	0.27	0.27	0.29
Effect on area with a floor price on paddy								
Irrigated paddy area	0.86	1.01	1.02	1.03	1.04	1.06	1.09	1.14
Irrigated chilli area	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Rainfed paddy area	0.09	0.23	0.24	0.25	0.27	0.28	0.32	0.36
Rainfed chilli area	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Effect on area with a floor price on paddy and chilli								
Irrigated paddy area	0.86	0.94	0.94	0.95	0.95	0.95	0.97	0.97
Irrigated chilli area	0.28	0.31	0.30	0.32	0.32	0.33	0.34	0.36
Rainfed paddy area	0.09	0.17	0.17	0.17	0.17	0.18	0.19	0.20
Rainfed chilli area	0.24	0.26	0.27	0.27	0.27	0.28	0.29	0.30

Note: * Mean acreage per farm household

floor price effects on the interdependence in area supply between crops and on the price responsiveness of the crops. or example, in *Maha* where the endogenous variable (final wealth) is significant in the chilli supply response equation, it is seen that the effects on paddy area and chilli area are in opposite directions, the direction and the intensity of the effect depending on the level of the floor price and the price responsiveness of the crop. But in *Yala* where the endogenous variable (final wealth) is insignificant in both paddy and chilli supply response equations, the simultaneity of the system is negligible, and the effects on paddy and chilli area are independent.

CONCLUSIONS

The results indicated that factors effecting area supply are different between crops and between seasons. In *Maha*, while access to land, irrigation and meeting household rice requirement were important for paddy, own profit expectations and expectations of final wealth were important for chilli. In *Yala*, for paddy, in addition to the above factors, own profit risks seemed important, and for chilli, own profit risk seemed to be the only important factor. Given the importance of own profit risk in area supply to a crop, it appears that field crop farmers are risk averse in *Yala*, but not in *Maha*. Refutation of the hypotheses of decreasing absolute risk aversion, constant relative risk aversion and constant partial relative risk aversion, in all except *Maha* season chilli cultivation, implies that changes in wealth or profits seem to have no effect on paddy area supply, and hence neither income transfers to farmers nor taxes/subsidies could effect changes in area supply. However, in the case of *Maha* chilli cultivation, income transfers are likely to influence chilli area supply. Decreasing absolute risk aversion has been a maintained hypothesis in economic literature. Rejection of the hypothesis in all cases, except *Maha* season chilli cultivation, casts doubt on the general premise that farmers display decreasing absolute risk aversion. The simulations demonstrate the profit mean increasing and risk reducing effects of floor prices and the importance of cross commodity effects in the formulation of price support programs. The simulations reveal that, given area supply to a group of crops are interdependent, floor prices can have different impacts on the crops, depending on the direction of interdependency in area supply as well as on the price responsiveness of the crops.

The results are in conformity with the observations made by researchers that farmers' priority to secure household rice requirements is a major factor which restricts farmers to paddy cultivation, despite lower net returns compared to other field crops. This underscores the importance of viewing the diversification issue not in isolation, but in relation to the paddy base. Agricultural policy, therefore, while concentrating on intensification of paddy production through increasing of productivity, which will allow farmers to meet household rice needs by concentrating on a lesser paddy area, should have price and yield support programs to reduce the risks in net returns from other field crops, if diversification is to take place. With increased productivity of rice, farmers relieved of the burden of cultivating paddy extensively, would be in a position to release more land to other field crops.

As for methodological implications, the study demonstrated the importance of considering area supply response in a multi-crop framework, modeling area supply to alternate crops as a system of simultaneous equations. The study further substantiated the importance of including variables representing risks and wealth in supply response models. Wealth effects have been omitted in traditional supply response models, barring examining the presence or the nature of risk aversion.

The model estimated supply response using cross section data at a point in time and precludes the inclusion of policy variables, as well as variables representing technological change, preventing the evaluation of the impact of government policies and technological change on area supply. Thus a time series of cross section data - a panel data set - would ideally overcome the limitations cited above. Cross section information will enable inclusion of variables representing risk and wealth, and time series information will enable inclusion of policy variables and variables representing technological change. Therefore a model using a set of panel data will allow analyzing an entire array of factors covering farm level to national level, influencing area supply.

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