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THE REGIONAL DIFFERENCES IN PRODUCTIVITY OF POTATO IN SRI LANKA

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ABSTRACT

The determinants of the regional differences in productivity and management practices of potato in Nuwara Eliya and Badulla districts were investigated using data obtained at the level of Agrarian Services Centre (ASC). First, the factors influencing the potato production are identified for Nuwara Eliya and Badulla districts using the Cobb-Douglas production function. The supply responses of farmers are identified by Nerlovian area response analysis. The production function analysis shows that the potato production is significantly influenced by the seed rate, farm size, labour utilization, rate of fertilizer and organic manure application, pests and diseases as well the seasonality effect. Most of the farmers use fertilizer mixtures and addition of excessive chemical fertilizers reduces the potato productivity while application of poultry manure or cow dung results in considerable improvement in productivity. The lower seed rate results in reduction in yield and the differences in seed rates contribute to the large yield differences among farmers in different ASCs. Nerlovian area response estimates reveal farmers are responsive to vegetable prices in *yala* (Badulla) and *maha* (Nuwara Eliya). Further, the analysis indicates that cultivation of potato is significantly influenced by relative prices of vegetables. A significant regional difference in productivity is observed and the results indicate the need of area based technological dissemination approach to increase the overall productivity of potato production in Nuwara Eliya and Badulla districts.

KEYWORDS: Potato, Production function, Supply response, Vegetable prices

INTRODUCTION

Potato (*Solanum tuberosum* L.) is grown mainly Nuwara Eliya and Badulla districts in the up country wet zone of Sri Lanka, and in few other districts in the intermediate and dry zones. In the up country, potato cultivation exists seasonally under rain-fed and irrigated uplands in both districts, and paddy lands especially in Badulla. A seasonal difference in the extent of cultivation and production of potato has been observed in both districts over the past decade. A 42 % drop in production was reported in the 1996/97 *maha* season at Nuwara Eliya, and the production continued to decline thereafter. In contrast, *yala* season had a 24 % drop for the same period but both the extent and production recovered by 79 % in 2002, and continued (DCS, 2008). The *yala* season in Nuwara Eliya has shown better performance in both extent and

production of potato while no apparent difference has been observed in Badulla. However, in terms of productivity, *yala* season (low land) is better than the *maha* season (high land) in Badulla district.

A significant shift from potato cultivation to upcountry vegetables has occurred in the past decade, particularly in the hilly areas of the wet zone (DCS, 2008). The improved performance of up country vegetables presumably reflects the farmer preference to grow more vegetables instead of potato, particularly in Nuwara Eliya and Badulla districts. In the midst of such scenario potato production should be encouraged as it provides the highest gross and net returns/ha, the highest return to labour and the highest return to a unit of fertilizer.[1] For instance, the return to labour (Rs/mandays) is the highest for potato (872) followed by cabbage (693)[2] and capsicum (602) in Nuwara Eliya, while it is the highest for potato (485) followed by pole bean (267) at Badulla. Interestingly, in the Badulla district, the return to labour for tomato was negative (-32). Moreover, the return to fertilizer (Rs/kg) is Rs. 165 and 92 for Nuwara Eliya and Badulla, respectively (Badulla: pole bean 89 and tomato 13, Nuwara Eliya: cabbage 184 and capsicum 166). However, poor agricultural practices and high cost of production could be attributed to the low yields observed in potato. Thus, there is a vital need to address the issues regionally, especially the differences in management practices.

The present study was carried out with the objectives to identify the (i) various factors responsible for yield variation in potato cultivation, (ii) responsiveness of vegetable prices vs. potato prices, and (iii) relative performance of management practices of potato cultivation, carried out in the Agrarian Service Centre (ASC) areas of Nuwara Eliya and Badulla districts.

MATERIALS AND METHODS

The data on potato cultivation, income and input use for the crop cultivation in Nuwera Eliya and Badulla districts were obtained from the primary surveys conducted for estimating cost of cultivation by the Socio Economic and Planning Centre of the Department of Agriculture (DOA, 2008a; 2008b). The 2006/07 *maha* and 2007 *yala* seasons were considered for the estimation of the production function. The sample size was 60 farmers in

[1] Calculations are based on Cost of Cultivation of Agricultural Crops (2006/07 *maha* for Nuwara Eliya and 2007 *Yala* for Badulla), Socio Economic and Planning Centre, Department of Agriculture.

[2] Vegetables were selected for the comparison with potato is based on the extents and the data availability in each district.

Badulla (pooled data for *yala* and *maha*) and 30 for Nuwara Eliya (separate samples for *yala* and *maha*). In estimating supplying response for the potato growing area, Nerlovian model was used separately for *maha* and *yala* seasons.

Time series data of cultivated extents of potato, wholesale prices of potato, wholesale prices of competing up-country vegetables were collected from 1985-2008. To evaluate the management performance of potato production in the areas of Agrarian Service Centers (ASCs), time series data were obtained for the period of 2005 *yala* to 2007/08 *maha* (3 years, 6 seasons). The ASCs selected were; Kappetipola (49)[3], Boralanda (35), Bogahakumbura (34), Uwa Paranagama (30), and Ambagasdowa (21) from Badulla and Nuwara Eliya (90), Helboda (38), and Ragala (34) for Nuwara Eliya district.

Analytical framework

Production function analysis was used to estimate the extent of effects of various factors influencing the potato yield. Cobb-Douglas production function was used to determine the factors and impact of various independent variables on yield due to its ease in computation and interpretation. Similar study has been conducted by Ahmad *et al.* (2005) to determine the various factors influencing carrot yield in Punjab. The following Cobb-Douglas production function was considered in the general form:

$$Y_i = \prod_{i=1}^{m} x_{ij}^{bi} e^{ui} \qquad \text{.....①}$$

where,

I = 1,2,....., m are inputs,
J = 1,2,....., n are number of farmers,
y_i = the output of j^{th} farmer,
x_{ij} = the level of i^{th} input on the j^{th} farmer,
bi = the parameters to be estimated,
u_i = error term, and
e = the natural log exponent.

[3] Values in parenthesis are the respective sample sizes

The above production function in log linear form is given below:

$$\ln y = A + \sum_{i=1}^{m} b_i \ln X_{ij} + \mu \qquad \text{.....②}$$

The details of the variables used for the districts are given in the given in Table 1.

Farm size could have positive or negative effect on the potato yield, as an increase in farm size results in economies of scale and it is also possible that modern technology could be applied. On the other hand, the possibility exists that with increased farm size, farmers would not be able to manage the farm more efficiently due to the limited resource availability or lack of knowledge, information, and education, especially technical. As a priori a negative sign was expected for the variable of damage occurrence due to rain/pests or other matters. Despite incorporation of these factors affecting the yield, many other factors were still left out. The performance of varietal difference could not be captured as almost all the respondents cultivated the same potato variety, Granola.

Table 1. Definition of variables

Variable	*Description*	*Expected sign*
LnPDN	Potato production (kg)	
LnSEED	Seed rate (kg/ha)	+
LnF_SIZE	Farm size (hactares)	+/-
LnFAM_LAB	Total family labour (mandays/ha)	+
LnT_LAB	Total labour (mandays/ha) (family labour + hired labour)	+
LnFERTI	Rate of fertilizer application (kg /ha)	+
D_DAM	Damage occurrence due to rain / pests / other = 1, Otherwise = 0	-
D_SEASON	Season: *Yala* = 1, *maha* = 0	+/-
D_ORG	Application of organic fertilizer = 1, Otherwise = 0	+

Note: All variables were tested in each model and come up with the most reasonable one. Therefore, all nine variables were not included in one model, *i.e.* LnFAM_LAB and LnT_LAB were used separately.

The Nerlovian model was used to assess whether the planting decision based on the prices that farmers expected to receive later at the harvesting time. Due to this time lag, it is crucial to model the formation of expectations in the analysis of area response. Since the aim of this study was to find out the

supply response of desired area to be allocated to potato at time t, the Nerlovian model of area response would be expressed as;

$$\ln A_{a,t} = \alpha + \alpha_2 \ln A_{at-1} + \alpha_3 \ln P_{potato,t-1} + \alpha \ln PI_{veg,t-1} + u_t \quad \text{.....③}$$

where,

$A_{a,t}$ = potato area in period t,

A_{at-1} = potato area (ha) lagged by one year,

$P_{potato,t-1}$ = wholesale potato price (Rs./kg) lagged by one year,

$PI_{veg,t-1}$ = price index of other competing vegetables lagged by one year, and

u_t = un-observed random factors; it has an expected value of zero (Perali, 2006)

In calculating the price index for upcountry vegetables, the types of vegetables were selected based on the cultivated extents. The wholesale prices for bean, cabbage, radish, tomato and capsicum were collected for Badulla and those for bean, cabbage, radish, carrot, leaks and beat were used for Nuwara Eliya. Seasonal wholesale price index was calculated, taking 1996 as a base year, for harvesting seasons (HARTI, 2007).

RESULTS AND DISCUSSION

Production function analysis

The Cobb-Douglas production function estimated the direction and the extent of various factors influence on potato yield. The selected variables explain about 84 % (Nuwara Eliya) and 98 % (Badulla) of variations in yield for *yala* and *maha* seasons (Tables 2, 3 and 4). Separate models for *maha* and *yala* seasons were estimated for Nuwara Eliya due to the existence of a prominent variation of potato cultivation between two seasons.

The results indicate that one per cent increase in the seed rate of potato increases the yield of potato by 0.497 and 0.167 per cent for *yala* and *maha* seasons respectively in Nuwara Eliya district and 0.887 per cent in Badulla district. It indicates that high plant population density increases the productivity of potato. Bakhsh *et al.* (2006) conducted a similar study on radish in Punjab and found the crop yield increased with increase of seed rate.

The coefficient of farm size (LnF_SIZE) was positive (1.251, 1.456; Tables 2 and 3) showing that an increase in farm size increase yield of potato in Nuwara Eliya, nevertheless Badulla showed a comparatively low coefficient of 1.025 (Table 4).

Table 2. Estimates of Cobb-Douglas production function for Nuwara Eliya: *yala* season

Variable	*Coefficient*	*SE Coefficient*	*T-value*	*P-value*
Constant	2.004	1.556	1.29	0.212
LnSEED	0.497	0.190	2.62	0.016
lnF_SIZE	1.251	0.136	9.20	0.000
LnFMLAB	0.168	0.102	1.64	0.116
LnFERTI	0.463	0.167	2.78	0.011
D_DAM	-0.461	0.182	-2.54	0.019
Adjusted R2			84	
F Value			28.39 (p=0.000)	

Table 3. Estimates of Cobb-Douglas production function for Nuwara Eliya: *maha* season

Variable	*Coefficient*	*SE Coefficient*	*T-value*	*P-value*
Constant	6.140	0.979	6.27	0.000
LnSEED	0.167	0.110	1.51	0.150
lnF_SIZE	1.456	0.051	28.78	0.000
LnT_LAB	0.183	0.072	2.53	0.021
LnFERTI	0.104	0.059	1.77	0.095
Adjusted R^2			97.9	
F Value			244.96 (p=0.000)	

Table 4. Estimates of Cobb-Douglas production function for Badulla

Variable	*Coefficient*	*SE Coefficient*	*T-value*	*P-value*
Constant	1.322	0.711	1.86	0.070
LnSEED	0.887	0.121	7.33	0.000
LnF_SIZE	1.025	0.060	17.09	0.000
LnTOT_LAB	0.245	0.122	2.02	0.050
D_ORG	0.248	0.074	3.36	0.002
D_SEASON	0.161	0.082	1.97	0.056
Adjusted R^2			90.6	
F Value			91.41 (p=0.000)	

This indicates that the increase of farm size in Badulla district would not increase the yield as much as in Nuwara Eliya district. It is a priori that the labor used in farm operations increases output. In this study, it was estimated that the direction of the effect of labor used (mandays/ha) was according to the expectation. One per cent increase of labour hours used for farm operation could cause an increase in the yield by 0.168 and 0.183 for *yala* season and

maha season, respectively, in the Nuwara Eliya district. Interestingly, family labor is the significant labour component for *yala* season whilst it is total labor (family and hired) for *maha* season in Nuwara Eliya. Generally a higher extent of potato could be cultivated in the *yala* season with fully-ultilized family labor. In contrast having lower extents in *maha* season, the potato farmers may tend to use hired labor in addition to the family labor. In the Badulla district, the total labor component is significant and had a coefficient of 0.245.

Potato needs substantial amounts of nutrients in the form of either organic or inorganic. In general, lesser number of potato growers apply farmyard manure while the majority uses chemical fertilizer. The coefficient of fertilizer (LnFERTI) indicates that 1 % increase in fertilizer nutrients (kg) could cause an increase in potato yield by 0.463 % in *yala* and 0.104 % in *maha* in Nuwara Eliya.

The dummy variable for seasonality (D_SEASON) revealed the presence of seasonal impact. Thus, relative to the *maha* season (high lands), the yields in *yala* season (low lands) were greater by 0.161 per cent in Badulla. This result coincides with the past production data of potato, where 46% of the total yield was from *maha* and 54% from *yala* (DCS, 2008). Crop damage (D_DAM) significantly reduces potato yield (0.461 per cent) in *yala* season in Nuwara Eliya (Table 2). The same dummy, which is associated with damage, was insignificant and eliminated from the model of Badulla.

The estimated supply response model indicates that the potato price, vegetable price and potato area together explains 42 % and 67 % of the observed variation of potato area in the Nuwara Eliya district for *maha* and *yala* seasons, respectively, and 37 % and 34 % of that observed in the Badulla districts for the *maha* and *yala* seasons, respectively (Tables 5 and 6).

Table 5. Estimates of Nerlovian model for Nuwara Eliya

	Nuwara Eliya maha			*Nuwara Eliya yala*		
Variable	*Coeff.*	*SE_Coef*	*T-value*	*Coeff.*	*SE_Coef*	*t-value*
Constant	3.364	1.283	2.62	0.955	1.073	0.89
Ln $PI_{veg,t-1}$	-0.308	0.147	-2.10	-0.561	0.304	-1.85
ln A_{at-1}	0.438	0.161	2.72	0.537	0.125	4.30
Ln $P_{potato,t-1}$	0.284	0.189	1.50	0.627	0.341	1.84
Adj R^2		41.7%			66.7%	
F value		0.005			0.000	

Table 6. Estimates of Nerlovian model for Badulla

	Badulla maha			*Badulla yala*		
Variable	*Coeff.*	*SE_Coef*	*T-value*	*Coeff.*	*SE_Coef*	*t-value*
Constant	3.715	1.250	2.97	2.898	1.559	1.86
Ln $PI_{veg,t-1}$	-0.228	0.127	-1.77	-0.442	0.216	-2.05
Ln A_{at-1}	0.411	0.176	2.34	0.431	0.191	2.26
Ln $P_{potato,t-1}$	0.237	0.172	1.38	0.421	0.240	1.75
Adj R^2		37%			34.2%	
F value		0.010			0.012	

The price elasticities of supply have the correct sign and are statistically significant in each model. Highest response, to the expected potato prices and expected prices of other competing vegetables and potato area is shown in Nuwara Eliya for *yala* season. The *maha* season of Badulla indicates the lower responses for the same parameters.

Descriptive statistics – Nuwara Eliya District

A large gap between the minimum and maximum yield (3,000-24,000 kg/ha) in the Nuwara Eliya ASC indicates that there is a critical need to minimize this gap (Table 7). The highest seed rate (kg/ha), cost of pest management (Rs/ha), cost of water management (Rs/ha) and unit cost of potato mixture (Rs/ha) were observed in the same ASC. The Helboda ASC possessed the highest gross income (Rs/ha) and interestingly, the highest percentage of farmers (80%) applying poultry manure.

Farm size is an indicator of the availability of resources and their impact on productivity. Helboda ASC is verifying the fact of relation between farm size and labour availability, *i.e.* larger farms with lower usage of family labour relate to hired labour. Moreover, the use of more hired labour indicates a greater degree of commercial production pattern.

Chemical fertilizer is an important input for higher production of potato. The potato farmers were found to apply several types of fertilizer namely, TSP, MOP, vegetable mixture, lime, urea, basal and organic fertilizer namely, cow dung and poultry manure. It is important to examine whether they are applying the correct dose.

Potato farmers in Nuwara Eliya district adhered mainly to the types of fertilizers; potato mixtures (usage <50 %), lime (usage >50 %) and poultry

manure (usage >50 % except in Helboda) only. The average application of potato mixture was 1,580 kg/ha (ranging from a maximum of 3,700 to a minimum of 250 kg/ha). Such a huge variation in the application of fertilizer was due to the differences in the unit cost, *i.e.* market prices of 1kg of fertilizer in 2008; TSP = Rs 127, MOP = Rs 117, Urea = Rs 103, Basal = Rs 96, TDM = Rs 83, Potato mixture = Rs 78[4].

Application rate of 1,580 kg/ha of potato mixture provides additional nutrients of 0.9 kg nitrogen, 2.9 kg phosphorus and 12 kg of potassium to one hectare of land. Thus, farmers must get used to the application of straight fertilizers. The cost associated with the recommended dose vs. actual application illustrates a monetary loss, *i.e.* cost of recommended dose/ha is Rs 95,000, cost in potato mixture of 1,580 kg/ha is Rs 123,000.

Descriptive Statistics - Badulla District

Out of the five ASC areas considered, the Bogahakumbura is rather a good example to illustrate that the application of excessive fertilizer never guaranteed a higher yield. The farmers at Keppetipola ASC are used to apply comparatively higher amount of potato mixture and lime. A tendency for increasing unit cost of production existed in the area of Boralanda ASC due to the higher use of hired labour. The lowest average yield/ha is reported from the Uwa Pranagama ASC area.

The application of the recommended seed rate would enhance the yield. The recommended potato seed rate ranged between 2,000-2,500 kg/ha. The lowest farm size occupied by Ambagasdowa ASC proved that small farmers are more efficient in having a labour force (family labour usage mandays/ha = 82%) together with adequate resources thus, managing the farm operations efficiently. On an average, the farmers were applying 1,272 kg of potato mixture and 593 kg of TDM for a hectare, which provide additional nutrients of 5 kg nitrogen, 2 kg of phosphorus and 19 kg of potassium to one hectare land.

[4] Fertilizer prices were obtained from Chemical Industries (Colombo) Limited (CIC) on Nov, 2008.

Table 7. Descriptive statistics of various variables in different ASCs in Nuwara Eliya and Badulla

Variable	*Nuwara Eliya District*				*Badulla District*			
ASC area	*Nuwara Eliya*	*Ragala*	*Helboda*	*Keppetipola*	*Boralanda*	*Uwa Paranagma*	*Ambagsdowa*	*Bogahakumbura*
Hectares	0.25	0.27	0.36	0.25	0.30	0.20	0.15	0.31
Yield (kg/ha)	13,437	14,378	14,264	11,211	11,615	9,719	10,857	13,389
Seed rate (kg/ha)	1,986	1,788	1,929	1,932	1,758	1,724	1,697	1,822
Seed cost (Rs/kg)	132	134	141	124	113	118	120	125
Tot family labour (man days/ha)	161 (79%)	153 (88%)	119 (92%)	183 (80%)	146 (88%)	158 (90%)	203 (95%)	158 (91%)
Tot hired labour (man days/ha)	222 (83%)	252 (88%)	230 (97%)	163 (78%)	198 (88%)	136 (90%)	158 (86%)	163 (82%)
Total Labour (man days/ha)	338 (93%)	398 (85%)	341 (97%)	331 (82%)	326 (85%)	301 (93%)	356 (90%)	306 (85%)
Cost Associated with Pest Management (Rs/ha)	37,381 (96%)	33,812 (94%)	26,256 (95%)	25,648 (88%)	30,317 (91%)	27,019 (100%)	34,743 (95%)	26,481 (100%)
Cost of water mgt (Rs/ha)	13,215 (76%)	11,473 (79%)	3,866 (45%)	6,938 (24%)	13,694 (32%)	1,554 (10%)	3,273 (19%)	10,085 (12%)
Method of Water Application (PUMP=1,Manual=0)	79%	76%	45%	29%	47%	7%	19%	15%
Income (Rs./ha)	748,610	711,308	722,268	516,907	563,076	408,321	480,328	589,266
Unit cost of Potato Mixture (Rs/kg)	37 (90%)	34 (82%)	32 (84%)	30 (61%)	31 (59%)	29 (90%)	28 (81%)	37 (65%)
Amount of Potato Mixture (kg/ha)	1,544 (90%)	1,606 (82%)	1,606 (84%)	1,457 (59%)	1,440 (65%)	1,272 (83%)	1,250 (71%)	931 (71%)
Unit cost of TDM (Rs/kg)	-	-	-	34 (55%)	32 (59%)	32 (76%)	39 (67%)	38 (79%)
Amount of TDM (kg/ha)	-	-	-	593 (55%)	524 (59%)	610 (67)	709 (76%)	519 (79%)

Table 7 (contd...). Descriptive statistics of various variables in different ASCs in Nuwara Eliya and Badulla

Variable	*Nuwara Eliya District*				*Badulla District*			
ASC area	*Nuwara Eliya*	*Ragala*	*Helboda*	*Keppetipola*	*Boralanda*	*Uwa Paranagma*	*Ambagsdowa*	*Bogahakumbura*
Cost of Liquid fertilizer (Rs/ha)	10,992 (42)	24,231 (47%)	7,245 (50%)	7,588 (33%)	6,667 (32%)	6,385 (33%)	5,849 (29%)	3,893 (29%)
Amount of Lime (bags/ha)	82 (36%)	277 (44%)	54 (44%)	47 (24%)	22 (50%)	17 (30%)	37 (38%)	27 (26%)
Cost of Lime (Rs./bag)	146 (36%)	218 (44%)	129 (42%)	138 (24%)	151 (38%)	156 (33%)	131 (43%)	129 (29%)
Cost of Poultry Manure (Rs/kg)	86 (31%)	63 (21%)	101 (74%)	-	-	-	-	-
Amount of Poultry Manure (bags/ha)	252 (31%)	163 (21%)	235 (79%)	-	-	-	-	-
Total cost of Chemical Fertilizer (Rs./ha)	67,937	67,658	65,892	63,625	64,074	62,844	73,757	54,461
Total cost of Organic Fertilizer (Rs./ha)	-	-	23,635	16,458	8,260	6,373	9,539	8,643
Gross income (Rs./ha)	706,882	718,696	723,389	513,108	512,523	436,669	510,258	629,813

Note: **Figures are the averages and values in the parenthesis are percentages. (The percentages > or ≈ 50% are recorded)**
For each variable the maximum and minimum values were calculated in addition to the average values.

CONCLUSIONS AND SUGGESTIONS

Results of the production function analysis revealed that seed rate plays an important role in increasing the yield of potato in both Nuwara Eliya and Badulla districts. Thus, the recommended seed rate would result in higher output and hence, the maximum income from growing potato. The dummy variable for damage occurrence either due to rain or pests was negatively associated with potato yield. Thus, diagnosis of disease and insect attack at the right time is the foremost element in potato management practices. The dummy variable to capture seasonality indicated that Nuwara Eliya district should focus and effectively allocate inputs in *yala* season. The optimum allocation of inputs at the proper season would increase potato yield. The study found that a higher percentage of farmers in both districts used to apply the potato mixture. Many farmers in the Badulla district applied TDM. Thus, the current per ha application of potato mixture in both Nuwara Eliya and Badulla districts provides additional nutrients to soil. The *yala* season of Nuwara Eliya highly responded to the potato extent, wholesale price of potato and up-country vegetables in previous year *vis-à-vis* in Badulla occupied the lowest response. The loss that can be recovered by a farmer who cultivates in the uplands of Nuwara Eliya and Badulla is Rs. 28,000 per ha while in lowlands of Badulla is Rs 53,000 per ha.

All these facts suggest that the soil-test based fertilizer formulation and use of straight fertilizers is a better option. The primary surveys indicated that the Helboda ASC, which the highest per ha yield, depicts the benefit of application of poultry manure. It is suggested that the Agriculture Instructors (AI) should emphasize the application of poultry manure and dry cow dung to the potato fields. Management practices adopted at Nuwara Eliya and Uwa Pranagama ASCs could be observed by AI's in order to minimize the large gap between the minimum and maximum per ha yield. The AI's role should be strengthened and broadened to check malpractices prevailing in potato fields especially in the application of the fertilizer and seed rates. On the basis of these results, the ASCs should refocus their functions towards profitable and sustainable potato production in Nuwara Eliya and Badulla districts.

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