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INVESTIGATING IMPROVED PASTURE PRODUCTIVITY CHANGE ON THE NEW SOUTH WALES TABLELANDS ¹

D.T. Vere

NSW Agriculture, Agricultural Research and Veterinary Centre, Forest Road, Orange, NSW, 2800, Australia.

Abstract: While less than 20 per cent of Australia's rural lands are amenable to pasture improvement, they support more than 70 per cent of the livestock population. There is now concern about a long-term decline in the productivity of improved pastures in the non-cropping areas, although there is little supporting evidence available. This paper attempts to establish the economic evidence of improved pasture productivity change on the New South Wales tablelands. It utilises index number and regression analyses to determine the patterns of pasture productivity change and to quantify the factors determining these changes. Based on these methods and a largely constructed data base, the overall conclusion was that there has been a small positive rate of change in improved pasture productivity over time, but there have been important differences in the productivity responses to changes in the main input categories.

1. Introduction

A number of statements over the past decade have alluded to a decline in the productivity of improved pastures in the grazing regions of south-eastern Australia. These comments have been mainly based on observations of reduced improved pasture quality and grazing performance, although supporting broad-scale evidence is difficult to locate. Archer, Read and Murray (1993) have provided a contemporary summary of the perception of declining improved pasture productivity. They stated that direct evidence for pasture decline was not readily available or documented; rather, it tended to be mainly anecdotal, a composite of widespread observations by producers, advisers and scientists. While detailed measurements over the last three decades were not available or were fragmented, the authors concluded from the little evidence available, that pasture productivity had declined over the last two decades.

Although sown pastures comprise only five per cent of Australia's total grazing areas, they support more than 70 per cent of all livestock (BAE, 1983). It has

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been estimated that 60 per cent of all pastures are grazed by sheep (Menz, 1984) and that improved pastures carry 180 million more sheep equivalents than unimproved pastures (Waring and Morris, 1974). The reality of improved pasture quality and productivity decline would therefore have major long-term implications for the grazing industries because livestock productivity and net grazing incomes are more responsive to changes in pasture availability and quality than to any other factor (Love *et al.*, 1982).

Livestock producers in south-eastern Australia have faced a generally adverse economic environment over the past 20 years which has seen heavy input cost inflation and highly variable product prices, particularly since the wool market deregulation in 1991. These trends have reduced the producer's ability to invest in pasture improvement and maintenance since expenditure on pasture inputs is closely correlated to farm income changes (Davis, Mullen and Bryant, 1979). Opinions differ as what factors have caused the perceived change-decline in improved pasture productivity, and the concern seems likely to have arisen from observations of reduced input use in pasture establishment and maintenance, and instances of increasing soil acidity and weed invasion.

Agricultural productivity analysis has become a major economic research area. Developments in the methods of productivity measurement and explanation have enabled their application to a wide range of productivity issues (Antle and Capalbo, 1988). This methodology offers opportunities for investigating the issue of improved pasture productivity change. However, the usefulness of any analysis utilising these methods is contingent on being able to measure the outputs from improved pastures and the inputs into them in a logical and consistent manner. This paper reports an attempt to apply economic methods to measure changes in the productivity of improved pastures in a major grazing region. The analysis relates to the central and southern tablelands of New South Wales which is one of Australia's foremost grazing areas. Improved pastures in this region comprise about 38 per cent of total farm holdings, with a range of 18 per cent in the Cooma-Monaro region to over 50 per cent for several shires in the central tablelands (1991-92 data). Livestock products contribute more than 75 per cent of the regional gross value of agricultural production, while the region has annually supplied an average 18, 12 and 10 per cent of the state's lamb, wool and beef production since 1980. Any long-term decline in the production status of the region's improved pastures would therefore have major economic implications for the region.

2. Background

It has long been recognised that Australia's predominant legume-based annual pastures become unstable and deteriorate over time (Trumble and Fraser, 1935). Legume pastures are dominant in the wheat-sheep zone where cereal crop expansion, over-grazing and reduced input usage have led to pasture quality decline (Carter, 1985). Similar trends are being observed with the legume-based pastures in the non-cropping areas where acid soils and weed invasion appear to be the main contributing factors. Acid soils now affect large

areas of the grazing regions and are said to be the result of the heavy use of fertilisers on pastures in the past. Weed invasion occurs when the increased soil nitrogen provided by the legumes is utilised by undesirable species in the absence of improved grass species. While there have been no attempts to measure the extent of change in the quality of these pastures on a broad scale, it is now accepted by pasture experts and producers that productivity problems have emerged with the legumes in the non-cropping areas and that these threaten to become long-term problems under the economic conditions facing livestock producers (M.H. Campbell 1993, *pers. comm.*). Archer *et al.* (1993) have identified a range of factors as likely causes of pasture decline; these include soil degradation and acidification, declining fertility, salinity, grazing management and pests and diseases.

The situation with the improved perennial grass pastures is more difficult to determine because the major improved grass species (phalaris, cocksfoot and ryegrass) differ considerably in terms of their persistence. Phalaris pastures can be maintained in a vigorous condition for many years under sound stocking and fertilizer management. Cocksfoot and ryegrass are more susceptible to insects and drought but can persist for long periods under good management. The main factors mitigating against the persistence of improved perennial grass pasture are over-grazing, acid soils and lack of fertilizer. Observations of an increasing incidence in these factors form the basis of the concerns about the degradation and reduced production status of these pastures.

Another factor has been the changes in improved pasture areas which have varied considerably over the 1980's. For example, the 1984 area was about 15 per cent below that of 1975, while the 1992 level was 11 per cent higher than 1984. The problem with basing concerns about changing pasture productivity on these statistics is that they do not indicate which pasture category these changes have been most prevalent. This distinction is important because a smaller sown pasture area may be equally or more productive than a previous larger area if there is a greater proportion of improved perennial grasses. The long-term carrying capacities of these species are much superior to either the annual legumes or the natural species. A well managed improved perennial grass-based pasture can support up to 15 dry sheep equivalents (dse's) per hectare compared with five dse's for legume pastures. Thus, a change in improved pasture activity as indicated by area statistics does not necessarily reflect a change in the productivity of those pastures.

3. Data

Pasture productivity in an economic sense is usually considered in terms of livestock production per head or per unit area. Factors influencing livestock productivity include improved pastures, labour efficiency, purchased inputs, and management. All these factors might be expected to be strongly correlated to pasture quality and thus, to pasture productivity. Here, pasture productivity is considered to be the livestock output from those portions of the regional

grazing area which support improved pastures. A distinction is made between the areas of improved perennial grasses and legumes within the total area.

Analysing change in pasture productivity over time using the established economic methodology requires data series on quantities of outputs and inputs and their respective prices and costs. Because there is a paucity of input-output data relating to improved pastures, the construction of the necessary data base has been a major focus. Few of these data are officially recorded for pastures. From its annual farm census, the Australian Bureau of Statistics (ABS) records the areas of improved pastures, livestock numbers and production, fertiliser usage and some other inputs for New South Wales local government areas. The Australian Bureau of Agricultural and Resource Economics (ABARE) assembles index series for the main types of livestock production and for disaggregated input use for the high rainfall, wheat-sheep and pastoral zones from the regular broadacre agricultural industries surveys. Again, these data do not specifically relate to pasture outputs and inputs.

The following procedures were used to devise the necessary output series where the objective has been to construct series to represent the volumes of livestock production from improved pastures and their two main categories - perennial grasses and legumes. The data period was 1951 to 1992, while the data areas are the New South Wales central and southern tablelands statistical divisions as defined by the ABS. The main data construction procedures are summarised in Table 1, while a condensed input file used to construct the data series is given in the Appendix.

Output series. ABS data on livestock populations and production and on the improved pastures provide a basis for calculating the necessary livestock output series. Data on sheep and cattle enable the total dry sheep equivalents (dse's) and their sheep-cattle proportions to be calculated using standard dse ratings (Table 1). While the ABS records wool production, and the numbers of lambs and calves, the volumes of meat production have to be calculated because stock transfers do not realistically allow the conversion of livestock numbers to a regional meat equivalent. This is because livestock disposal statistics do not indicate their purpose, i.e., whether disposal for slaughter or for breeding or production purposes. Also, many animals are sold for slaughter outside the region in which they were bred and regional abattoirs similarly process stock from elsewhere.

The main requirement has been to estimate the total dse's supported by the region's improved pastures. This was held to be the total stock which were not carried on native pastures. Native pasture stocking rates have been the subject of considerable recent debate with the current belief that they have previously been substantially underestimated. Tucker, Clinton and Manglesdorf (1968) reported that native pastures on the New South Wales tablelands supported an average 1.875 dse's per hectare. More recent evidence from the central and southern tablelands found that these pastures are now carrying about four dse's per hectare (Garden, Dowling and Eddy, 1993). Regional pasture experts

Table 1: Data Construction Procedures for Major Variables for Total Tablelands

<u>Constructed regional variable</u>	<u>Official base data (ABS)</u>	<u>Derivation of constructed variable</u>
Total grazing area (a)	(b) area of holdings (c) area of crop	(b) - (c)
Native pasture area (d)	(e) improved pasture area	(a) - (c)
Native pasture stocking rate (f)	none	estimated from weighted average of log. function estimates for 1951-60, 1961-78, 1979-92
Sheep dse's	(g) sheep types	breeding ewes * 2.2; other ewes and wethers * 1.0; lambs * 0.6; rams * 1.6
Cattle dse's	(h) cattle types	breeding cows * 12.0; calves and others * 6.0; bulls * 10.0
Dse's on native pastures (i)	none	(d) * (f) = stocking rate * area for native pastures
Dse's on improved pastures (j)	none	((g) + (h)) - (i) = total regional dse's - dse's on native pastures
Sheep dse's on improved pastures (k)	none	(j) * ((g) / (g) + (h)) = dse's on improved pastures * % of sheep in total regional dse's
Cattle dse's on improved pastures (l)	none	(j) - (k) = (total dse's - sheep dse's) on improved pastures
Area of perennial grasses (m)	Kemp & Dowling (1991)	(e) * 0.18 = area of improved pastures * % perennial grasses
Dse's on perennial grasses (n)	none	(m) * 10
Area of legumes	none	(e) - (m) = area (improved pastures - perennial grasses)
Dse's on legumes	none	(j) - (n) = dse's (improved pastures - perennial grasses)
Wool production by pasture type	wool production	sheep dse's on pasture type * average wool cut/dse
Lamb production by pasture type	lamb numbers	lambs on pasture type * 0.65 * 17.5 = lambs * % sold for meat * average carcass weight
Beef production by pasture type	cattle numbers	cattle on pasture type * % sold for beef * average carcass weight (325 kg)

attribute this diversity to the continual modification of native pastures with fertilisers, legume introduction and grazing since the early 1950's. As the native pasture stocking rate was the basis for determining its improved pasture counterpart and the corresponding output series. This stocking rate was estimated from a relationship in which the overall stocking rate per hectare was considered to be a function of the proportion of improved pastures in the total grazing area². The native pasture stocking rate was held to be the constant term in this relationship, and was estimated to be about 2.65 dse's per hectare for the region over the full data period.

Applying this stocking rate estimate enabled the stock numbers on improved pastures for each region to be determined and the output series for wool, lamb and beef from these pastures to be derived as follows:

wool: regional wool production was divided by total sheep dse's to give an average wool cut per dse; this was then multiplied by the total sheep dse's on improved pastures to yield their wool output.

lambs: since most lambs produced on the tablelands are meat types, 65 per cent total lambs were assumed to be disposed of for slaughter at an average dressed weight of 17.5 kilograms (NSW Agriculture lamb expert estimates); the number of lambs involved was estimated from their proportions in the total sheep dse's on improved pastures, and multiplied by the former parameters to yield the output of lamb on these pastures.

beef: similar procedures determined the quantity of beef which was based on the proportions of each cattle category normally disposed of for slaughter (NSW Agriculture beef cattle expert estimates) and their relative shares of the total cattle dse's grazed from improved pastures.

Improved perennial grasses and legumes (clovers, medics and lucerne) are the main components of the region's improved pastures but there is limited available information on their relative proportions in the overall improved pasture area. As previously indicated, this distinction is important because the former category has a much superior long-term carrying capacity. Also, the perception of changing pasture productivity appears to be mainly concerned with the latter. One survey by Kemp and Dowling (1991) found that improved perennial species and legumes each comprised about 21 per cent and 60 per cent of all pastures on the central tablelands over 1988 and 1989. While this estimate is most time-specific, it provides an indication of the relative perennial grass-legume proportions, and in the absence of prior supporting information, it

² This was derived as a weighted average of logistic function estimates for three sub-sample periods (1951-1960, 1961-1978 and 1979-1992). The sub-samples reflected significant changes in pasture improvement activity which occurred in the region.

was assumed to have held constant over the data period for the region³. This allowed the area of improved pastures to be disaggregated into its two main components and the livestock outputs from these to be estimated following the same procedures as described above. The main assumption here was to set the perennial grass stocking rate at 10 dse per hectare as an average over the range of tablelands environments after Vere, Campbell and Kemp (1993).

Input series. ABARE assembles a range of farm input and price series from its regular surveys of the grazing industries. These series include land, capital, plant and structures, permanent and casual labour, services, contracts and materials. Aggregate input series are also estimated. The input series related to the survey's sheep industry section for the high-rainfall zone and these were assumed to adequately relate to the New South Wales tablelands. Both the individual input series and composites of these were used in this analysis. The main composite series were to aggregate fixed inputs (land, plant-structures and capital series), aggregate variable inputs (labour, contracts, services, materials and livestock) and a total of all inputs. Input price series were derived from the ABARE indexes of prices paid by farmers in New South Wales.

4. Methods

Productivity is the rate of output per unit of input and is determined by the scale, technical efficiency and state of technology of the production process. Productivity measures are broadly classified as estimates of total productivity to all inputs or of partial productivity to a specific input or groups of inputs. The basic concept in productivity measurement has become total factor productivity (TFP) (Antle and Capalbo, 1988). TFP represents the ratio of an index of aggregate output to an index of aggregate input for a given state of technology. In the absence of technological change, output growth is directly explained by the growth in total input use, where increased output per unit of input can be gained either from more efficient resource use (disembodied technological change), or by using better quality inputs (embodied technological change). New technology adoption is likely to produce a residual output which is not explained by measurable input growth. Factors determining the residual include expenditure on R&D, time trends and the weather.

The TFP residual is the basic concept in the measurement and explanation of productivity change. As such, most of the methods used in productivity analysis concerns TFP measurement and are classified as being either index number-growth accounting methods or various econometric methods which quantify input-output relationships. Under both types of methods, the change in productivity is considered to be the level of output not explained by input use.

³ This assumption is certainly debatable and its veracity remains to be established.

and exogenous influences determine the level of productivity growth. Many applications in the productivity literature report comparative analyses utilising elements of both methods. Choice of method is mainly based on data needs and availability and the validity of the underlying assumptions, particularly about the functional form of the production process⁴.

Index numbers indicate the relative rates of change in economic variables over time and are constructed for individual inputs and outputs and for aggregates of these. These series can be used to provide both partial factor productivity (PFP) and TFP estimates. The main types of index numbers used in productivity analysis are the Paasche, Laspeyres and Tornqvist-Theil indexes, each of which makes restrictive assumptions about input substitutability (e.g., the first two imply that all inputs are perfect substitutes). The preference for TFP measurement which arises from the practical difficulties in identifying the output contributions of the separate resources (Christensen, 1975), necessitates the use of aggregate indexes of outputs and inputs. These indexes are most commonly constructed using the Divisia indexing procedure which provides a consistent means of aggregating multiple outputs or inputs into a single series based on a weighted average of the rates of change in the components continuously over time (Jorgenson and Griliches, 1971).

The other types of indexes indicated above can be shown to be discrete approximations of the continuous Divisia index but differ in terms of the aggregating procedure adopted and the restrictions associated with their assumptions. The Tornqvist-Theil index has gained favour in application because it implies a translog production function which is more flexible and imposes fewer restrictions than other functional forms⁵. This index assumes that producers are competitive, that the production function is linearly homogenous, that the state of technology is separable in inputs and outputs, and that Hicks neutrality applies. Equations (1) and (2) give the general form of Divisia indexes for aggregate output (Q) and aggregate input (X) defined in terms of their proportional rates of growth. The ratio of these equations gives the proportional rate of growth of TFP.

$$(1) \quad \delta Q = \sum_j (p_j Q_j / \sum_j p_j Q_j) \delta Q_j$$

$$(2) \quad \delta X = \sum_j (W_j X_j / \sum_j W_j X_j) \delta X_j$$

where, W and X are input price and quantity vectors and δ denotes a proportional change. The Tornqvist-Theil discrete approximations of these Divisia indexes are given (from Antle and Capalbo, 1988) as:

⁴ These methods are detailed and compared in Antle and Capalbo (1988).

⁵ This indexing procedure appears to be that adopted for estimating Divisia indexes by the TSP econometric package which has been used in this analysis.

$$(3) \ln(Q_t/Q_{t-1}) = 0.5 \sum_j (S_{jt} + S_{j,t-1}) \ln(Q_{jt}/Q_{j,t-1})$$

$$(4) \ln(X_t/X_{t-1}) = 0.5 \sum_i (S_{it} + S_{i,t-1}) \ln(X_{it}/X_{i,t-1})$$

where, S denotes the input shares for each period. The corresponding equation for TFP is:

$$(5) \ln(TFP_t/TFP_{t-1}) = \ln(Q_t/Q_{t-1}) - \ln(X_t/X_{t-1})$$

The use of econometric methods in productivity measurement involves estimation of the production process to explain the relative changes in the productivity determinants. These methods specify a relationship which expresses output as a function of input and thus provide the link between TFP and production theory. Production, cost and profit functions are commonly used to estimate the components of TFP into the explained conventional input and unexplained residual components. The Cobb-Douglas production function has often been estimated in this context. This function is relatively easy to estimate but is restrictive in its assumptions, particularly about the elasticities of factor substitution which are held to be constant and unitary⁶. These restrictions can be overcome by respecifying the Cobb-Douglas as a translog function in which the production elasticities are linear functions of the inputs (on the condition that $\alpha_i = \alpha_0 + (0.5)\sum_j \alpha_{ij} \ln X_j$);

$$(6) \ln Q = \ln \alpha_0 + \sum_i \alpha_{i0} \ln X_i + (0.5) \sum_i \sum_j \alpha_{ij} (\ln X_i)(\ln X_j)$$

Both index number and econometric methods were used in this analysis. The index numbers were expected to indicate the reality of productivity change, and the econometric methods to identify the determinants of any such change.

Index numbers. PFP and TFP ratios were constructed for both the outputs of improved pastures and the inputs into these. Regional aggregate outputs were derived from the wool, lamb and beef production series for the total areas improved pastures, perennial grasses and legumes. The PFP input series were aggregates of fixed (land, capital and plant and structures) and variable inputs (labour, contracts, services and materials) which were based on the ABARE input series previously described. Divisia quantity indexes for aggregate outputs for each pasture category and a series of the total of all inputs were

⁶The general form of the Cobb-Douglas function is;

$$(7) Y = AX_1^\alpha X_2^\beta$$

where, Y is output, X_1 and X_2 are two inputs and A, α and β are the parameters to be estimated. This function can be estimated linearly in logs using the form;

$$(8) \ln Y = \ln A + \alpha \ln X_1 + \beta \ln X_2$$

also constructed. Because the weighting procedure adopted for calculating the Divisia index components has been shown to affect the actual quantity change and the resulting TFP estimate, these indexes were estimated using a combined weighting system that specified the weights to be the geometric average of the arithmetic average and the shares in the current and previous periods (TSP, 1993). This was considered to be the safe option because there was little indication of what the real nature of the weighting pattern of the changes in prices and quantities have been over the data period. All input prices were in nominal values and the index numbers were normalised on the 1953 value = 100.

Econometric methods. Regression methods were used to estimate input-output relationships in which the TFP estimates and the individual outputs by pasture category variables were the dependent variables. Because the TFP is the measure of the net change in output which is not explained by changes in conventional inputs, the estimated TFP ratios were regressed on several other non-conventional inputs to attempt to determine their separate influences. These were variables which were not included in the input indexes and were an index of annual average rainfall, dummy variables to represent significant changes in the pasture improvement environment in the region (such as the release of new subterranean clover varieties in the early 1950's) and the removal of the superphosphate bounty in 1975, and a time trend.

Cobb-Douglas functions were estimated for wool, lamb and beef production from total improved pastures, perennial grasses and legumes on a total area basis. This functional form was considered to be appropriate on two grounds. First, it assumes a joint relationship between inputs where output responds to changes in the inputs in combination rather than to inputs independently. When livestock output is considered as an economic proxy for pasture productivity, it is reasonable to assume that the inputs and exogenous factors interact jointly to determine output. Second, it enables the analysis of change in individual input levels by holding other input levels constant, provided that the input coefficients do not change. Changes in outputs to input changes might be examined by comparing the base function estimates with the simulated input level changes. For example, the labour input could be reduced the resulting change in wool production compared with the base estimation. A negligible change would suggest that labour was relatively unimportant in a regional wool production function.

Translog cost functions were also specified for the aggregate livestock outputs for each pasture category. These functions incorporated five conventional inputs (land, capital, plant and structures, labour and the Divisia index of variable inputs) and a rainfall index. No results have been obtained from these models at this stage because of estimation problems. All estimates were obtained using the TSP econometric package (Version 4.2; TSP, 1993) from annual data between 1953 and 1989, and first-order autocorrelation corrections were applied where necessary.

5. Results and Discussion

The results reported in this section relate to the total tableland (central and southern) region⁷. Table 2 contains the estimated PFP and TFP ratios. For the PFP ratios, a t-statistic analysis based on the paired first-differences of the PFP ratios of aggregate output to both fixed and variable inputs for each pasture type, is reported in lieu of the actual series to establish if there were differences in the rates of change in the two input series over time. The null hypothesis test was that the input series for each common output had the same mean. Rejection of this hypothesis meant that each series differed and hence, there were differences in their relative rates of change and in their impacts on output.

The PFP results indicate important differences in how pasture productivity has changed in response to changes in the fixed and variable input categories. The trends in the PFP series have been similar for each pasture category, but there have been differences in the response of outputs to each input category and also in the average rates of change in PFP. For each pasture type, PFP increased steadily to the end of the 1960's, rose substantially in the early 1970's, and declined thereafter, particularly in relation to fixed inputs. The early trends reflect the gradual increase in improved pasture areas and the livestock production increases this permitted over this period. The high outputs over 1970-72 appear to be the result of the high sheep population which precipitated the collapse of the Australian wool market. Analysis of the variance of the PFP's for each pasture type indicated that the PFP series were more variable for the fixed than the variable inputs, and that the legume PFP series were the most variable. The t-statistics tests for the paired PFP ratios indicated rejection of the null hypothesis in each situation which inferred that there had been differences in the effects of changes in the fixed and variable inputs on livestock output-pasture productivity over the period.

Each of the average per cent changes in productivity were negative for the fixed inputs and strongly positive for the variable inputs, and were higher for the perennial grasses than for the legumes. The former result reflects the increased capital value of grazing properties relative to the value of the livestock they produce. ABARE estimates of low and at times, negative real rates of return to capital in the grazing industries support this result. On the contrary, the relatively high average rates of productivity change to the variable inputs for each pasture category is more difficult to explain. Although there have been several periods of very high returns to livestock production, such as for beef cattle in the mid 1970's, the most likely explanation appears to be the onset of input cost inflation during the same period. Dillon (1977) suggested that livestock productivity gains can be illusory and result from input use

⁷ Estimates were derived for both the central and southern tablelands regions; only the total estimates are reported here due to space requirements. Regional differences are to be examined as an extension of this study.

Table 2: Partial and Total Factor Productivity Ratios for Total Tablelands: 1953 to 1989

Input $\Rightarrow$ Outputs $\Downarrow$	<u>Sown Pastures</u>			<u>Perennial grasses</u>			<u>Legumes</u>		
	PFP to fixed inputs	PFP to variable inputs	TFP to aggregate inputs	PFP to fixed inputs	PFP to variable inputs	TFP to aggregate inputs	PFP to fixed inputs	PFP to variable inputs	TFP to aggregate inputs
1953	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1955	1.13	1.04	0.98	1.34	1.23	1.16	1.10	1.01	0.95
1957	1.44	1.25	1.29	1.78	1.54	1.59	1.38	1.20	1.24
1959	1.53	1.28	1.24	1.83	1.53	1.48	1.48	1.23	1.20
1961	1.66	1.37	1.43	1.74	1.43	1.50	1.65	1.36	1.42
1963	1.85	1.44	1.49	1.85	1.44	1.48	1.85	1.44	1.48
1965	1.93	1.22	1.51	1.98	1.26	1.55	1.92	1.22	1.49
1967	2.03	1.91	2.17	1.97	1.84	2.10	2.05	1.91	2.18
1969	1.97	1.67	1.99	1.96	1.66	1.98	1.97	1.68	2.00
1971	2.71	2.61	3.25	1.81	2.11	2.61	2.81	2.71	3.37
1973	2.38	3.07	3.46	2.20	2.84	3.20	2.42	3.12	3.51
1975	2.16	3.60	4.59	1.84	3.08	3.93	2.22	3.70	4.72
1977	1.57	4.07	4.31	1.37	3.56	3.77	1.60	3.17	4.41
1979	1.08	3.02	3.27	1.19	3.34	3.62	1.06	2.96	3.21
1981	0.58	3.05	3.46	0.69	3.58	4.05	0.56	2.67	3.35
1983	0.51	1.79	2.24	0.69	2.42	3.02	0.48	1.68	2.09
1985	0.46	2.76	3.44	0.56	3.30	4.11	0.45	2.16	3.32
1987	0.39	2.56	2.97	0.44	2.92	3.39	0.38	2.48	2.90
1989	0.36	2.47	3.47	0.39	2.72	3.81	0.35	2.43	3.40
Average % change	-3.61	8.16	1.41	-3.91	11.44	2.87	-3.61	7.94	1.32
t-statistics $H_0: \mu_1 = \mu_2$	-3.57			-3.61			-3.59		

deferral rather than from input adjustments. This conclusion was confirmed by Easter (1977) when in examining of Australian sheep industry trends between 1971 and 1976, found that apparent declines in sheep productivity in the early 1970's and increases over 1974-75, were exactly offset by changes in input use in those years. The very high apparent increases in sheep productivity over 1974-75 was due to input use deferral in expectation of low sheep output prices and incomes.

TFP for each pasture category has followed a similar upward trend and has been maintained at a relatively higher level than PFP in more recent times. One noteworthy result is that the average rate of change in the TFP of the perennial grasses has been about double that of both the total sown pasture area and the legumes. The trends in the total sown pasture and legume categories are similar because of the legumes comprise about 80 per cent of total sown pastures. Given the low level of inputs into legume pastures relative to the perennial grasses and that the input deferral arguments are likely to apply equally to both pasture types, the productivity of the perennial pastures seems to have been maintained at a higher level than that of the legumes. This suggests that graziers have perceived greater economic benefits in maintaining perennial pastures than legumes when confronted by cost-price pressures.

Regressing the three TFP ratios on the non-conventional inputs provided little explanation of the change in productivity relative to changes in these inputs (these results are not reported in a table). Each equation had a low R^2 and mainly insignificant coefficient values. The technology dummy variable lagged one period was marginally significant in the equations for total sown pastures and perennial grasses, while the time trend was significant in each equation, suggesting that TFP has increased in response to changes in aggregate input use. No rainfall effects on TFP could be determined in either of the three equations. Including of a lagged dependent variable resulted in a significant coefficients on these variables and substantial increases in the R^2 's. However, the conclusion that current period TFP is strongly influenced by its previous period value does not appear to be outstanding.

The Cobb-Douglas function estimates for the three products and pasture categories are given in Table 3. Additional equations for the per unit area (hectare) dependent variables are also included as a comparison to the total area estimates. The estimates indicate that much of the change in livestock productivity for each of the pasture categories was influenced by change in the respective dse populations for sheep, cattle and lambs, and in either fixed or variable inputs. For the input categories, fixed inputs and labour were significant determinants of wool production while beef production was most influenced by changes in variable inputs. There were no significant input effects in lamb production. No explanation seems to be plausible for these differing input effects. The time trend was marginally significant in the three total area lamb equations. Again, the rainfall index provided little explanation of productivity change. The total and per unit area results followed similar patterns in terms of the nature and strength of their determinants. These results suggest that the livestock productivity of each pasture category has changed positively over time, and that this has been mainly due to the

Table 3: Estimates of Cobb-Douglas Functions (t-statistic values)

Dependent variable	Independent variables						Adj. R ²
	Dse numbers ¹	Index of fixed inputs	Index of variable inputs	Index of labour inputs	Index of land and capital	Time trend	Rainfall index
Wool - sown pastures	21.55	4.38		2.89			0.96
Wool - per ha sown pastures	12.26	5.59		3.30			0.83
Wool - perennial grasses	15.94	3.44		2.81			0.95
Wool - per ha perennial grasses	8.87	4.71		1.50			0.81
Wool - legumes	22.91	4.49		2.91			0.96
Wool - per ha legumes	13.44	5.45		3.45			0.85
Beef - sown pastures	61.57		2.28				0.66
Beef - per ha sown pastures	29.14		2.55				0.79
Beef - perennial grasses	48.70		2.07				0.58
Beef - per ha perennial grasses	24.23		2.87				0.56
Beef - legumes	63.81		2.31				0.67
Beef - per ha legumes	31.04	1.00	2.48				0.81
Lambs - sown pastures	11.39					1.79	0.94
Lambs - per ha sown pastures	4.97		1.43		1.14		0.62
Lambs - perennial grasses	4.99					1.49	0.95
Lambs - per ha perennial grasses	6.24	2.19	1.23				0.73
Lambs - legumes	13.25					1.99	0.97
Lambs - per ha legumes	6.24		1.24		1.46		0.68

Notes: ¹ number of dse's of each livestock type by pasture category and area

increases in carrying capacity that the expansion in improved pasture areas has permitted. Given the previously-stated definition of pasture productivity as being equivalent the output of livestock products, this implies that the productivity of the three pasture categories has similarly increased, i.e., changes in livestock equivalents and in input levels have positively influenced livestock production and therefore the productivity of the pastures on which it depends. As such, the results partly contrast the TFP ratios which indicated a declining trend for aggregate livestock to the fixed inputs. One explanation may be that the functional estimates over the full period may disguise the real nature of the productivity changes which may have occurred within this data period. A more rigorous test would be to examine the stability of the estimated coefficients within the estimation sample using a test for structural change.

6. Summary and Concluding Comments

This analysis has attempted to establish whether there has been change in the productivity of improved pastures on the New South Wales tablelands and what has been the direction of that change. While it has utilised established procedures for measuring productivity changes, the validity of the results obtained has been very much dependent on the reliability of the constructed data series relating to the livestock output from the main pasture categories and the inputs into these. Some of the assumptions on which the data series have been derived can certainly be debated as the critical parameters have either had to have been estimated or obtained from a very small literature which does not claim to be representative of all areas or time periods.

Overall, the results provide some evidence of a positive change in improved pasture productivity. The PFP estimates indicate that aggregate livestock productivity and hence, the productivity of the individual pasture categories has declined relative to fixed inputs but there have been strong productivity increases relative to variable input use. The first PFP result appears to reflect the declining returns to the capital base in livestock production which has been observed in ABARE's farm surveys. In the second, reduced expenditure on variable inputs (particularly fertilizers) is likely to have been a major factor in the apparent increase in productivity to this category of inputs. Previous analyses of sheep productivity change have identified this phenomenon. The TFP estimates indicate small average rates of growth in livestock-pasture productivity to aggregate input use which has been most pronounced with the perennial grasses. Attempts to disaggregate the non-conventional determinants of these TFP were largely inconclusive although strong lagged TFP effects were found in each equation. The regression results available to date also suggest that there have been positive changes in improved pasture productivity over the data period but the possibility of structural change within the period remains to be confirmed. Also, the results derived from the restrictive Cobb-Douglas functional form need to be compared with those to be obtained from the translog cost function models which are expected to be completed in the short term.

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APPENDIX

THIS IS THE DATA TRANSFORMATION FILE TO ANALYSE PASTURE PRODYUCTIVITY

FREQ A \$ SMPL 51 92 \$

? calculating TOTAL variables

GENR THOLD = CHOLD+SHOLD \$

GENR TCROP = CCROP+SCROP \$

GENR TIPAST = CIPAST+SIPAST \$

? calculating the total grazing areas ('000 ha)

GENR TGZA = THOLD-TCROP \$

? calculating area of native pasture ('000 ha)

GENR TNATP = THOLD-TCROP-TIPAST \$

? % of sown grasses in grazing area (%)

GENR TIPGZA = TIPAST/TGZA \$

? calculating sheep dse ('000)

GENR CSDSE = ((CRAMS*1.6)+(CBEWE*2.2)+(CNBEWE*1.0)+(CWETH*1.0)+(CLAMB*0.6)) \$

GENR SSDSE = ((SRAMS*1.6)+(SBEWE*2.2)+(SNBEWE*1.0)+(SWETH*1.0)+(SLAMB*0.6)) \$

GENR TSDSE = CSDSE+SSDSE \$

? calculating cattle dse ('000)

GENR CCDSE = ((CBULL*10.0)+(CBCOW*12.0)+(CNBCOW*6.0)+(CCALF*6.0)) \$

GENR SCDSE = ((SBULL*10.0)+(SBCOW*12.0)+(SNBCOW*6.0)+(SCALF*6.0)) \$

GENR TCDSE = CCDSE+SCDSE \$

? total regional dse ('000)

GENR CTOTDSE = CSDSE+CCDSE \$

GENR STOTDSE = SSDSE+SCDSE \$

GENR TTOTDSE = CTOTDSE+STOTDSE \$

? regional dse per ha of grazing area

GENR TDSEHA = TTOTDSE/TGZA \$

? calculate dse on native pastures ('000)

SMPL 51 65 \$

GENR TDSENP = TNATP*2.657 \$

? dse on sown pastures ('000)

GENR TDSESP = TTOTDSE-TDSENP \$

? dse per ha sown pasture

GENR TDSESPHA = TDSESP/TIPAST \$

? dse per ha native pasture

GENR TDSENPHA = TDSENP/TNATP \$

? ratio of sheep dse to total dse (%)

GENR TSTDSE = TSDSE/TTOTDSE \$

? ratio of cattle dse to total dse (%)

GENR TCTDSE = TCDSE/TTOTDSE \$

? ratio of dse on native to sown pasture (%)

GENR TDSENPSP = TDSENP/TDSESP \$

? sheep dse on sown pasture ('000)

GENR TSHSP = TDSESP*TSTDSE \$

? sheep dse per ha sown pasture

GENR TSHSPHA = TSHSP/TIPAST \$

? cattle dse on sown pasture ('000)

GENR TCTSP = TDSESP-TSHSP \$

? cattle dse per ha sown pasture

GENR TCTSPHA = TCTSP/TIPAST \$

? wool per dse (kg)

GENR TWLDSE = ((TWOOL*1000)/TSDSE) \$

? wool from sown pastures (kt)

GENR TWLSP = ((TWLDSE*TSHSP)/1000) \$

? wool per ha sown pastures

GENR TWLSPHA = (TWLSP*1000)/TIPAST \$

? area of perennial grasses ('000 ha)

GENR TPGSP = TIPAST*0.18 \$

? area of legumes ('000 ha)

GENR TLEGSP = TIPAST-TPGSP \$

? sheep dse on perennial grasses ('000)

? stock at 10 dse per ha over both regions

GENR TSDSEPG = TPGSP*10*TSTDSE \$
 GENR TSDPGHA = TSDSEPG/TPGSP \$
 ? cattle dse on perennial grasses ('000)
 GENR TCDSEPG = TPGSP*10*TCTDSE \$
 GENR TCDPGHA = TCDSEPG/TPGSP \$
 ? sheep dse on legumes ('000)
 GENR TSDSELG = TSHSP-TSDSEPG \$
 GENR TSDLGHA = TSDSELG/TLEGSP \$
 ? cattle dse on legumes ('000)
 GENR TCDSELG = TCTSP-TCDSEPG \$
 GENR TCDLGHA = TCDSELG/TLEGSP \$
 ? total dse on perennials
 GENR TTDSEPG = TSDSEPG+TCDSELG \$
 ? total dse on legumes
 GENR TTDSELG = TSDSELG+TCDSELG \$
 ? calculate wool production from perennial grasses (kt)
 GENR TWLPG = (TSDSEPG*TWLDSE)/1000 \$
 ? wool per ha perennial grasses
 GENR TWLPGHA = (TWLPG*1000)/TPGSP \$
 ? wool production from legumes (kt)
 GENR TWLEG = (TSDSELG*TWLDSE)/1000 \$
 ? wool per ha legumes
 GENR TWLEGHA = (TWLEG*1000)/TLEGSP \$
 ? calculate regional lamb production (kt)
 GENR TVOLAMB = (TLAMB*0.65*17.5)/1000 \$
 ? calculate lamb production from sown pastures (kt)
 ? lambs as a % of total sheep (%)
 GENR TTOTSHP = TBEWE+TNBEWE+TWETH+TRAMS+TLAMB \$
 GENR TLDSE = TLAMB*0.8 \$
 GENR TLPROP = TLDSE/TSDSE \$
 ? calculate lambs on sown pastures ('000)
 ? lamb dse's on sown pastures ('000)
 GENR TLDSESP = TLPROP*TSHSP \$
 GENR TLDSPHA = TLDSESP/TIPAST \$
 ? lambs on sown pastures ('000)
 GENR TLAMBSP = TLDSESP/0.8 \$
 GENR TLDSESP = TLAMBSP*0.8 \$
 ? lamb production on sown pastures (kt)
 GENR TLPRODSP = (TLAMBSP*0.65*17.5)/1000 \$
 ? calculate lamb production from perennial grasses (kt)
 ? lambs on perennial grasses ('000)
 GENR TLAMBPG = (TSDSEPG*TLPROP)/0.8 \$
 GENR TLDSEPG = TLAMBPG*0.8 \$
 GENR TLDPGHA = TLDSEPG/TPGSP \$
 ? lambs on legumes ('000)
 GENR TLAMBLG = TLAMBSP-TLAMBPG \$
 GENR TLDSELG = TLAMBLG*0.8 \$
 GENR TLDLGHA = TLDSELG/TLEGSP \$
 ? calculate regional beef production (kt)
 GENR TTOTCAT = TBCOW+TNBCOW+TCALF+TBULL \$
 GENR TCALFDSE = TCALF*7.0 \$
 GENR TCPROP = TCALFDSE/TCDSE \$
 ? regional beef production (kt)
 GENR TVOLBEEF = (TCALF*0.85*325)/1000 \$
 ? calculate beef production on sown pastures ('000)
 ? calf dse's on sown pastures ('000)
 GENR TCDSESP = TCPROP*TCTSP \$
 ? calves on sown pastures ('000)
 GENR TCALFSP = TCDSESP/7.0 \$
 ? beef production on sown pastures (kt)
 GENR TBPRODSP = (TCALFSP*0.95*325)/1000 \$
 ? calculate beef production from perennial grasses (kt)
 ? calves on perennial grasses ('000)
 GENR TCALFPG = (TCDSEPG*TCPROP)/7.0 \$

calves on legumes ('000)
NR TCALFLG = TCALFSP-TCALFPG \$
lamb prod. /ha sown pastures (t)
NR TLPSPHA = (TLPRODSP/TIPAST) \$
lamb prod./ha perennials (t)
NR TLPRODPG = (TLAMBPG*0.65*17.5)/1000 \$
NR TLPPGHA = (TLPRODPG/TPGSP) \$
lamb prod./ha legumes (t)
NR TLPRODLG = (TLAMBLG*0.65*17.5)/1000 \$
NR TLPLGHA = (TLPRODLG/TLEGSP) \$
beef prod. /ha sown pastures (t)
NR TBPSPHA = (TBPRODSP/TIPAST) \$
beef prod./ha perennials (t)
NR TBPRODPG = (TCALFPG*0.95*325)/1000 \$
NR TBPPGHA = (TBPRODPG/TPGSP) \$
beef prod./ha legumes (t)
NR TBPRODLG = (TCALFLG*0.95*325)/1000 \$
NR TBPLGHA = (TBPRODLG/TLEGSP) \$