AN ASSESSMENT OF FACTORS ASSOCIATED WITH INCREASED PRODUCTIVITY OF DAIRY FARMS IN FIJI

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Summary

A survey of physical inputs was conducted on the total population of dairy farms supplying milk to the Rewa cooperative dairy company in Fiji. The critical inputs associated with total farm milk production were determined using multiple regression, with analyses being conducted for each of the three identified supplier groups, bulk milk, canned milk and cream. Mean annual milk production per cow averaged 1460 (s.d. = 319), 889 (s.d. = 321) and 800 (s.d. = 451) litres for the bulk milk, canned milk and cream suppliers respectively. Stocking rate averaged 1.37 (s.d. = 1.18) cows per hectare over all farms. Inputs to pasture were universally low and Navua sedge (*Cyperus aromaticus*) was identified as a major weed. The average amount of supplement fed annually on a grain equivalent basis was 700 (s.d. = 984) kg per cow for bulk milk, 84 (s.d. = 198) kg per cow for canned milk and 146 (s.d. = 542) kg per cow for cream suppliers. The analysis of data from a small group of farms using nitrogen fertiliser indicated that their production levels were higher than the general population. This suggests that there is potential for the Fijian dairy industry to increase milk production through the use of higher inputs to cows and pastures. The regression models relating annual milk production from farms to the two key inputs of number of cows milked and the amount of supplement fed were all significant ($p < 0.001$). The coefficients of determination for these models ranged from 56.9 to 89.4 percent.

(**Key Words** : Dairying, Farming System, Regression, Fiji)

Introduction

After the First World War a dairy industry was organised in Fiji based on three factories. Rewa Cooperative Dairy Company (RCDC) is the sole survivor of the original factories and services the present industry which is based in the districts of Navua, Vunidawa and Tailevu on the eastern side of the island of Viti Levu (Dairy Profile, 1987). A total of 171 farms supply either cream, canned milk or bulk milk to this factory. Viti Levu is located at 18° south latitude and between 177° and 179° east longitude; it has a mean annual rainfall of 1,640 mm and a climate described as tropical oceanic (Carter, 1984).

This study identifies the major physical inputs associated with milk production on Fiji dairy farms using data collected from a survey conducted in 1991. The analysis of these data provides an accurate baseline of inputs and outputs for use in planning, and indicates where gains in efficiency might be made. A similar survey was carried out in Queensland, Australia in 1986-87 and, in addition to supplying basic summary statistics, the analyses of these data have identified the major factors associated with milk production on dairy farms in Queensland. The survey has also provided a baseline that has been used by the Queensland dairy industry to estimate productivity increases over time. (D. V. Kerr, unpublished data).

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Materials and Methods

A survey of all dairy farmers supplying milk or cream to the Rewa Cooperative Dairy Company in Fiji was conducted in October 1991. These farmers were categorised as one of three types of suppliers namely, bulk milk, canned milk or cream. The main difference between supplier groups is in the price they are paid for milk. Bulk suppliers received a premium price of 30.9 cents per litre for whole milk. Cream suppliers received five dollars per kg of butterfat and canned milk suppliers received the same 30.9 cents per litre as the bulk suppliers, but were required to pay an additional two cents a litre cooling charge (A. Murray, pers. comm.).

The data collection method was by personal interview with a total of 164 out of the population of 171 being able to supply all the information needed.

Fifty-eight questions on the physical characteristics of the farm and 155 questions on farmer attitude and perceptions were asked and answers entered on a questionnaire. The physical farm data were used for the derivation of statistical models, while the information on the attitudes and perceptions of dairy farmers provided an insight into why some farmers adopt certain practices (Murray et al., 1991). This paper will concentrate on the description and analysis of the physical farm data. Some attitudes and perceptions obtained from the personal interviews have been used to help explain why farmers have adopted some technologies and not others.

Total farm milk production was obtained from factory records. Annual butterfat production from cream suppliers was converted to a milk equivalent assuming 4% butterfat test. This enabled a direct comparison of production levels for each farm.

Data on feed inputs were summarised into seven variables which represented the major areas of technology available, and thus provided a baseline estimate of the present technology used in the Fiji dairy industry. The variable 'energy' was obtained from the total amount of supplement fed to all milkers on the farm for the year, multiplied by metabolizable energy content (MJ/kg) of each supplement (NRC, 1989). The variable 'nitrogen' was expressed in kilograms of the element applied as fertiliser. The amount of land available to the dairy herd for grazing was recorded as the variable 'dairy area', which was expressed in hectares as were the variables 'improved pasture area', 'native pasture area' and 'navua sedge area'. Improved pastures contained some or all of the species, para grass (*Brachiaria mutica*), setaria (*Setaria anceps*), panic species (*Panicum spp*) and paspalum (*Paspalum dilatatum*), while the native pastures contained one or more of the species, mat grass (*Axonopus affinis*), blady grass (*Imperata cylindrica*) and batiki blue grass (*Ischaemum indicum*). Navua sedge (*Cyperus aromaticus*) has a low feed value and is considered a weed in Fiji (Black, 1984). Because of its association with low milk production, it was included as a separate variable. The variable 'number of cows milked' was obtained by adding milking cows recorded at the time of interview with the number of dry adult cows on the farm. This calculation ensured that all adult females contributing to total annual farm milk production were counted. The predominant milking breed throughout Fiji at the time of the study was Friesian, although many of these cows were considered small with average liveweight estimated by experienced dairy extension officers to be around 400 kg. Milk production per cow was obtained by dividing total production by the number of cows milked. The variables 'stocking rate' and 'milk production per hectare' were also derived by appropriate division.

Separate analyses were conducted for the bulk milk, canned milk and cream suppliers, as these were seen as potentially different populations. Initial analyses indicated that both the variables milk production per cow and milk production per hectare had low correlations with all farm inputs. These poor relationships are due to the different ways cows can be managed to produce milk; the same level of production for a farm can be obtained by either milking more cows with lower per cow production levels (higher stocking rate) or milking less cows with higher production (higher production per cow). Since it is important to incorporate this potential management choice into any model at estimating a farmer's production expectations, it was determined that the dependent variable for these analyses should be total annual milk production (litres per year). The relationship between this dependent variable and farm inputs were significant.

Regression analysis techniques were used to identify variables that made an important relative contribution to the variation in productivity. A variable was considered important if its partial regression coefficient was significant at the 95 percent level of confidence.

Since the objective of this study was to model total farm milk production for the general population of Fiji dairy farms, some farms that were atypical of the population were omitted from the main regression analysis. Twelve farms (four bulk milk, six canned milk and two cream) were omitted on the basis of one or more of the following; abnormally large amounts of improved pastures, small areas set aside for dairying, small numbers of cows being milked or a milk to concentrate ratio of less than 1.25 l/kg which is a minimum acceptable ratio for a diet which does not have an excess of concentrates (T. Cowan, pers. comm.). This latter figure was determined from a survey conducted in Queensland, Australia in 1990/91 (Kerr and Chaseling, 1992). An additional eight farms that were applying more than 200 kilograms of nitrogen fertiliser per farm per year were excluded, as the scale of their production was much higher than the population in general (table 1). It should be noted that on some farms nitrogen was applied in amounts so small that they were considered to be below the minimum required to obtain an effect on farm production. These farms were not excluded; for example, one farm applied 12 kilograms of nitrogen annually over the whole farm.

TABLE 1. COMPARISON OF IMPORTANT VARIABLES AND TOTAL DAIRY AREA FOR FARMS APPLYING IN EXCESS OF 200 KILOGRAMS OF NITROGEN PER FARM PER YEAR WITH THE REST OF THE POPULATION

Variable	Parameter	nitrogen[1] (n=8)	no nitrogen[2] (n=144)
Total dairy area (hectares)	Mean	173	45
	Standard Deviation	65	40
Number of cows milked throughout the year	Mean	246	48
	Standard Deviation	139	44
Total farm milk production (liters per year)	Mean	437,219	50,568
	Standard Deviation	278,742	66,519
Supplementary energy fed (MJ per year)	Mean	2,856,232	218,154
	Standard Deviation	1,850,816	537,465
Nitrogen applied as fertiliser (kg per year)	Mean	1,087	1
	Standard Deviation	1,373	9

[1] Farms with nitrogen in excess of 200 kg per farm per year.
[2] Farms with nitrogen application rates of less than 200 kg per farm per year.

The low levels of nitrogen in the main group of farms was such that no significant response to nitrogen occurred, thus nitrogen does not appear as a significant component in the regression models. To demonstrate the possible effect of nitrogen at a level greater than 200 kg per farm, the estimates of the total farm milk production which could have been expected had these eight farms belonged to the non-nitrogen group, were obtained using the appropriate regression model for each of the three supplier types. These estimates were compared with actual farm milk production. It should be noted that any difference in production levels between 'nitrogen' and 'non nitrogen' farms is not necessarily due only to the application of nitrogen fertiliser, for example, farmers who use nitrogen may also adopt other technologies more readily. However, this approach was felt to be of value in distinguishing between two apparently different farmer populations.

Results

A summary of the basic statistics of each variable measured for all farms is shown in table 2. Bulk milk suppliers had larger total dairy area per farm, milked more cows and produced approximately ten times the annual milk production of both canned milk and cream suppliers (table 2). The 31 bulk supply farms accounted for 67 percent of the milk supplied to the factory. Production levels per cow were low, with the bulk milk suppliers averaging 1460 litres per cow per year and the cream suppliers averaging 800 litres per cow per year (table 2).

The mean level of supplementary energy fed to each cow by bulk milk suppliers was 9,385 megajoules, equivalent to 700 kilograms of grain per cow per year. This indicates a milk to grain ratio of 2.08 l/kg. The canned milk and cream suppliers fed around 84 and 146 kilograms of grain equivalent per cow per year respectively, with a milk to grain ratios of 10.6 and 5.5 l/kg.

Limited amounts of nitrogen were applied over the whole farm in the bulk milk supplier group with an average of five kilograms of nitrogen applied per hectare for all bulk milk farms. On average, 29, 42 and 31 percent of the farm was invaded by Navua sedge for the bulk milk, canned milk and cream suppliers, respectively.

For all three supplier types the significant independent variables ($p < 0.05$) were the number of cows milked and the amount of supplementary energy fed. The relative value of each input to the total farm milk production can be seen from the partial regression coefficients in the model, as these represent the response rate of milk to the input (table 3). A partial regression coefficient indicates the amount of additional milk expected from a specific input in the model. For example, with bulk milk suppliers, the addition of one cow for a fixed energy level would provide an extra 1,058 litres of milk per year. Similarly, if the cow numbers remain constant an extra 0.044 litres of milk would be expected for each additional megajoule of supplementary energy fed each year over the whole farm.

Since these coefficients are estimates from a sample of data, the 95% confidence intervals of response are also provided to help in valid interpretation of the true

TABLE 2. MEAN AND STANDARD DEVIATION (s.d.) FOR EACH VARIABLE FOR THE THREE CATEGORIES OF SUPPLIER AND OVER ALL FARMS

Variable	Parameter	Bulk milk suppliers	Canned milk suppliers	Cream suppliers	All Suppliers
Number of farms		31	52	81	164
Total farm milk production	mean	273,063	29,762	32,278	76,994
(litres per year)	s.d.	193,852	27,861	35,361	129,574
Supplementary energy fed	mean	1,698,767	38,676	80,194	372,980
per farm (MJ per year)	s.d.	1,423,685	69,008	247,029	903,895
Nitrogen applied as fertiliser	mean	771	154	12	197
(kilograms per year)	s.d.	1,109	1,109	72	1,389
Total dairy area	mean	153	46	45	65
(hectares)	s.d.	146	68	60	94
Number of cows milked	mean	181	34	41	65
throughout the year	s.d.	108	26	34	78
Area of native pasture	mean	79.5	19.6	24.1	33.1
(hectares)	s.d.	81.0	13.3	22.1	48.9
Area of improved pasture	mean	26.6	4.9	5.4	9.3
(hectares)	s.d.	74.5	14.3	23.4	37.8
Area of Navua sedge	mean	43.7	19.2	13.8	21.1
(hectares)	s.d.	44.0	27.8	28.5	33.5
Stocking Rate	mean	1.68	1.34	1.28	1.37
(cows per hectare)	s.d.	1.71	1.26	0.82	1.18
Milk production per cow	mean	1,460	889	800	953
(litres per year)	s.d.	319	321	451	461
Milk production per hectare	mean	1,079	602	399	592
(litres per year)	s.d.	1,214	1,108	324	878

TABLE 3. PARTIAL REGRESSION COEFFICIENTS AND DETAILS OF THE MODEL FOR TOTAL MILK PRODUCTION PER FARM FOR SIGNIFICANT VARIABLES ($P < 0.05$) FOR EACH SUPPLIER TYPE AND FOR COMBINED SUPPLIER TYPES, EXCLUDING 20 FARMS CONSIDERED TO BE ATYPICAL OF THE POPULATION. STANDARD ERRORS ARE SHOWN IN PARENTHESES, 95% BOUNDS RELATE TO THE RESPONSE RATE FOR SUPPLEMENTARY ENERGY FED

Partial regression coefficient	Bulk milk suppliers	Canned milk suppliers	Cream suppliers	All suppliers
Constant	1,864	6,830	8,688	−3,211
	(27,881)	(2,609)	(2,777)	(2,729)
Number of cows milked	1,058	497	389	828
throughout the year	(225)	(93)	(67)	(61)
Partial coefficient of determination (%)	59.0	48.5	39.6	79.8
Supplementary energy fed	0.044	0.088	0.070	0.070
(MJ per farm per year)	(0.016)	(0.030)	(0.007)	(0.006)
Lower 95% bound	0.017	0.037	0.058	0.060
Upper 95% bound	0.071	0.139	0.082	0.080
Coefficient of determination (%)	71.9	56.9	75.5	89.4
Number of farms	21	46	77	144
Root mean square error	36,374	8,642	13,315	20,275

relationship within the population.

The response rate to supplementary energy from the model used to predict total farm milk production varied from 0.044 litres of milk per megajoule of supplementary energy for bulk milk suppliers to 0.088 litres of milk per megajoule for canned milk suppliers. The combined supplier types rate was 0.07 litres per megajoule. These estimate are similar to the response rate of 0.074 (standard error of 0.013; 95% confidence bounds of 0.052 and 0.096) found from a sample of 103 Queensland dairy farms (Kerr and Chaseling, 1992).

The estimates and upper 95% confidence bound for the eight nitrogen farms obtained using the appropriate group regression equation from table 3 are given in table 4 along with the actual total farm milk production for each farm. The regression models, in general underestimated total farm production for these farms (table 4), with the actual observed production of four farms being above the upper 95% confidence limit.

TABLE 4. ESTIMATED AND ACTUAL TOTAL FARM MILK PRODUCTION LEVELS FOR THE NITROGEN FERTILISED FARMS (IN EXCESS OF 200 KILOGRAMS OF NITROGEN USED PER FARM PER YEAR)

Farm group	Estimated milk production per farm per year (l)	Upper confidence limit (95%)	Actual mik production per farm per year (l)
Bulk	619,449	737,350	748,789
Bulk	584,068	691,657	752,490
Bulk	250,382	309,825	157,015
Bulk	570,379	660,056	623,920
Bulk	477,611	560,707	536,508
Bulk	451,396	530,418	472,166
Cream	62,769	67,633	111,600
Cream	41,524	44,995	95,265

Discussion

Milk production per cow was low compared with other dairying areas throughout the world. Black (1984) has recognised that this low production and resultant low returns make it difficult for Fijian farmers to improve their farm as they are unlikely to have money for control of weeds or to improve pastures.

Another dairy industry which lies in the same latitude, has a similar climate and the same breed of cows, is found in the Atherton Tablelands in Queensland. The present average production level per cow for the Atherton Tablelands is 4,200 litres (Kerr and Chaseling, 1992) and was 1,800 litres with a variation of between 634 and 1735 litres per cow in 1950-51 (Mawson, 1953). The inputs in Queensland during 1950-51 were very similar to those in present day Fiji, with very little supplement being fed apart from molasses (Mawson, 1953), and minimum development of improved pastures. Although little molasses is fed in Fiji it is estimated that the level of supplemental energy obtained from concentrates fed is similar to that described by Mawson (1953).

On the Atherton Tablelands the technologies used to increase production have been irrigation, introduced temperate and tropical pasture species, supplementation, nitrogen fertiliser and hay or silage (Cowan, 1985). In Fiji it appears that the most applicable technologies would be the introduction of new pasture species, the application of nitrogen fertiliser and the increased use of molasses as a supplement for dairy cows. Queensland experience suggests that it is possible to obtain per cow milk production levels of up to 3,500 litres per year on nitrogen fertilised tropical pastures alone (Cowan, 1985), thus major gains in productivity would be expected from an improved pasture base in Fiji. The present analysis indicates that well-managed farms in Fiji with higher than average nutritional inputs and fertiliser inputs have higher total farm milk production levels and appear to be more efficient compared with the rest of the population (tables 1 and 4). Since supplementary energy is accounted for in the models, having response rates similar to those expected in similar situations (table 3), it is suggested that the extra milk is due to improvements in both the quality and quantity of pasture available to the milking herd.

Another indicator of low pasture productivity is the level of infestation of Nauva sedge. The sedge (*Cyperus aromaticus*) is considered a major cause of low milk production, and is described by Black (1984) as the worst weed in the Fiji islands both in terms of area covered and loss of productivity to the dairy industry. Black also observed that this sedge has a very low feed value and cattle graze it only when no other feed is available. Karan (1975, 1976) also described Navua sedge as the most serious weed in Fiji and estimated that it can reduce livestock carrying capacities by up to 40 percent. In addition, studies conducted in Fiji have shown that the application of nitrogen fertiliser encourages grass growth and suppresses the ingress of Navua sedge and other weeds (Krishna et al., 1986). Similarly, workers in Queensland have found that fertilising pastures has resulted in desirable grasses becoming dominant over weeds associated with low soil fertility, such as mat grass

(*Axonopus affinis*) and blady grass (*Imperata cylindrica*) (Garther, 1969).

In Queensland, molasses is fed to dairy cows as a supplement and response rates of 0.7 litres of milk per kilogram of molasses have been measured (Chopping et al., 1980). This supplement is a by-product of the sugar industry, a major industry in Fiji, and feeding it to dairy cows could be a cost-effective method of increasing milk production. At a cost for molasses of 11 cents per kilogram delivered on the farm, an additional litre of milk would cost 15.7 cents to produce. This would give a margin of 15.2 cents per litre for milk priced at 30.9 cents per litre, the price quoted for Fiji bulk farms. Similarly, nitrogen fertilised grass has shown a return of 8 litres of milk per kilogram of nitrogen applied (Reason et al., 1989), suggesting a margin of 12.5 cents per litre when urea fertiliser with a nitrogen content of 46 percent costs 27 dollars per 40 kilogram bag.

The attitude and perceptions section of the survey estimated that 53 percent of dairy farmers identified poor infrastructure, including roads, as a major problem affecting their farm (Murray et al., 1991). This poor transport network could make the supply of molasses and fertilisers difficult on many dairy farms, and could slow the adoption rate of this technology. This problem was identified as extreme for many canned milk and cream suppliers many of which tended to be in underdeveloped areas.

Milk responses to supplementary feeding are similar to those estimated from the Queensland study (Kerr and Chaseling, 1992) for both canned milk and cream suppliers, although the response rate is lower for bulk milk suppliers. The standard error of the estimate for both bulk and canned milk suppliers is large compared with cream suppliers. This variation could be due to the smaller sample sizes as seen with the wide confidence interval for bulk milk suppliers of 0.017 to 0.071 as compared with the equivalent interval for all suppliers of 0.060 to 0.080 (table 3). The 0.044 response rate to supplementary feeding for bulk milk suppliers (table 3) is lower than the 0.074 l/MJ or 1.0 l/kg of grain equivalent estimated from data obtained from the survey of 103 Queensland dairy farms conducted in 1990-91 (Kerr and Chaseling, 1992). However, the upper 95% confidence bound of 0.071 l/MJ or 0.95 l/kg on a grain equivalent basis, lies in the middle of the 95% confidence interval for the Queensland data (0.052 to 0.096 l/MJ or 0.70 to 1.29 l/kg on a grain equivalent basis). Response rates from the other two supplier types are similar to that estimated from the Queensland study. The lower response for bulk milk suppliers in Fiji may well reflect a similar response to that which applied in Queensland when its dairy industry was at the same stage of development. Queensland farms showing this level of response in the 1950-51 period at that stage of development may have either improved their efficiency or left the industry.

This study suggests that there is a low level of productivity from pastures in Fiji with low milk production levels per cow (table 2). These levels are similar to those recorded on the Atherton Tableland of Queensland in the early 1950's (Mawson, 1953). Queensland experience suggests that much higher levels of production per cow can be obtained by increasing inputs of nitrogen fertiliser and supplements such as molasses. Potential increases in production in Fiji have been indicated by the level of total farm milk production obtained on some dairy farms that already apply nitrogen fertiliser and feed substantially higher amounts of supplements than the population average for their respective supplier type.

Literature Cited

Black I. D. 1984. Navua sedge in pastures in Fiji, Australian Weeds 3(1):16-19.

Carter J. 1984. Pacific Islands Year Book, Pacific Publications, Sydney.

Cowan R. T. 1985. The Challenge: Efficient Dairy Production, Australian Society of Animal Production Dairy Production Conference, Albury-Wodonga 25-28 March 1985.

Chopping G. D., L. J. Smith, I. K. Buchanan and P. K. O'Rourke. 1980. Molasses supplementation of Friesian cows grazing irrigated Couch/Pangola pastures. Proceedings of the Australian Society of Animal Production 13:401-404.

Dairy Profile. 1987. A program for future development of the dairy industry, Ministry of Primary Industries, Fiji.

Gartner J. A. 1969. Effect of fertiliser nitrogen on a dense sward of Kikuyu, Paspalum and Carpet grass 1. Botanical composition, growth and nitrogen uptake, Queensland Journal of Agricultural and Animal Sciences 26:21-33.

Karan B. 1975. Studies of Navua sedge (Cyperus aromaticus) Part 1. Review of the problem and study of morphology, seed output and germination, Fiji Agricultural Journal 37:59-76.

Karan B. 1976. Studies of Navua sedge (Cyperus aromaticus) Part 2. Control studies, Fiji Agricultural Journal 38:61-72.

Kerr D. V. and J. Chaseling. 1992. A study of the level and efficiency of production in relation to inputs for dairy farms in Queensland (DAQ77): Final Report Queensland Department of Primary Industries, Brisbane, Australia.

Krishna M., M. Nacola and P. Tagitagivalu. 1986. Navua Sedge control by three grasses under a range of management practices, Annual Research report, Research Division, Department of Agriculture, Ministry of Primary Industries, Fiji.

Mawson W. F. 1953. The Dairy Industry on the Atherton Tableland. Queensland Agricultural Journal 76:19-37.

Murray A., R. Fell and D. V. Kerr. 1991. Needs Assessment of Rewa Cooperative Dairy Suppliers, Fiji. A report to the Rewa Cooperative Dairy Company Fiji.

NRC. 1989. Nutrient Requirements of Dairy Cattle, Subcommittee on Dairy Cattle Nutrition, National Research Council, National Academy Press, Washington, D.C.

Reason G. K., J. Bodero, K. F. Lowe, G. E. Rayment and McGuigan. 1989. Milk production from nitrogen fertilised rain grown pastures, (DAQ49): Final Report Queensland Department of Primary Industries, Brisbane, Australia.