AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Systems Analysis of Livestock Waste Management: A Study of Large-Scale Dairying

S. C. Matulich, H. F. Carman, and H. O. Carter

The analytical approach to studying waste management is investigated here in the context of large scale dairying. The typical short-run approach that regards waste management as separable from primary production is contrasted with a longer-run systems approach in which waste management is regarded as an interdependent stage of production. Failure to consider interdependencies between waste management and agricultural production could compromise potential effeiciencies in the overall system. Furthermore, cooperative waste treatment and disposal among livestock producers may contribute to greater efficiency and afford opportunities for resource conservation and recovery through waste utilization.

Consolidation of dairy production into fewer but larger, specialized units is one facet of the transformation of western agriculture. Greater herd confinement along with advances in milking systems, feeding, and general herd management have contributed to significant increases in productivity. However, the efficiency gains arising from these new production processes often conflict with environmental quality. Much of the conflict stems from waste disposal problems that are amplified by large scale confinement operations.

For agriculture in general and dairying in particular, the waste management problem can be viewed from two perspectives. One is the short-run objective of satisfying impending or existing environmental quality regulations. Because of its urgency, this problem has received much attention in the literature [Van Arsdale and Johnson, Good, and Ashraf and Christensen]. This short-run focus, however, has fostered the general belief that waste management is an engineering feat; that is, a separate treatment and/or disposal process to be "added-on" to the production system. While enabling compliance with environmental standards, this short-run perspective may be myopic, providing only a stop-gap measure. It seeks to minimize waste treatment/disposal costs, thereby ignoring opportunities to increase overall production efficiencies by integrating waste management into the production process.

A systems approach to waste management provides a longer-run view that attempts to maintain efficient agricultural production in harmony with desired environmental quality standards. This longer-run solution explicitly recognizes the interdependencies between waste management and the production system. Hence, a systems approach to waste management should lead to more efficient

S. C. Matulich is Assistant Professor of Agricultural Economics at Washington State University, and H. F. Carman and H. O. Carter are Professors of Agricultural Economics at the University of California at Davis. This paper was developed from research supported by the California Agricultural Experiment Station, University of California, Davis and the Agricultural Research Center, Washington State University. The authors are grateful to George Tchobanoglous, the anonymous *Journal* reviewers, and to Carole Nuckton for her editorial assistance.

overall production than treating waste management decisions as separable or additional components to the production process.

A case study of large scale dairies in the Chino Valley of Southern California is used here to compare the economic implications of the traditional short-run approach to waste management with the systems approach. Average size herds of 600 cows are confined on 10 to 60 acres; several herds are in excess of 2000 cows. Over 20 percent of California's dairy herd, approximately 167,000 cows, are concentrated within this 50 square mile region. With over 9000 tons of manure and 8 million gallons of waste water produced daily, only 12,500 acres of irrigated pasture and cropland are suitable for waste disposal. Hence, industry concentration further accentuates the waste disposal difficulties.

In 1972, the Santa Ana Regional Water Quality Control Board implemented a two-phase regulatory program on Chino Valley dairies to control water quality deterioration caused by inadequate waste management practices. The program limits the amount of manure and wash water discharged to the land and prevents runoff. Compliance requires adoption of improved waste management practices, placing considerable economic stress on the competitive situation of the Chino dairy industry.

Analytical Framework

The added-on and the systems approach to waste management are compared in terms of relative waste treatment and disposal cost rankings. Differences in relative rankings are taken to impart analytical importance to the method of studying waste management. For example, if the least cost waste management process differs between the two approaches, the systems approach would be selected as analytically superior on grounds of greater overall production efficiency.

Comparison of the two approaches entails a two step procedure. First, costs of various waste management processes are computed independent of supportive adjustments in the dairy production systems. Second, interdependencies between the stages of dairy production and waste management processes are identified and modeled in a simulated dairy production system to assure harmonious integration of waste management into the overall production system. However, the cost of such integration is not simply the sum of waste management process costs and supportive dairy adjustment costs. The potential for opportunity costs in the form of foregone efficiency in dairy production arises. It is conceivable that required dairy adjustments could compromise overall production efficiency to such an extent as to yield a relative process ranking different from that obtained via simple summation. Thus, the systems approach rankings are based upon long-run average costs for the various integrated dairy production/waste management systems.

Unlike conventional analyses of cost functions which involve only internal economies of size to the firm, the nature of the Chino Valley dairy waste problem warrants analysis of external economies of size as well. The extent of water pollution in the Chino Basin is primarily attributable to dairy industry concentration. However, industry concentration may in fact afford external economies of size from region-wide waste management which are only available collectively to individual dairies. Thus, internal economies in regional waste treatment/disposal were analyzed.

Step One: The Separable Approach

A region-wide waste management program not only offers the potential to reduce costs of complying with environmental quality regulations but also broadens the scope of relevant waste treatment/disposal options. Waste treatment and disposal techniques previously considered uneconomic for use by commercial livestock enterprises may become economically feasible in the context of regional waste management. While technical feasibility of such processes has been recognized for many years, inadequate scale has been an impediment to their adoption. Individual

dairies, even the extremely large ones of the Chino Valley, simply cannot realize essential scale economies. Accordingly, regional waste treatment and disposal processes common to municipal/industrial applications are modeled, as well as commercial processes originally designed for livestock applications. The traditional approach of spreading wastes on dairy-owned or controlled land is regarded here as subordinate to a regional process, and is restricted in application to the water quality regulations.

Cost estimates for the alternative regional waste treatment and disposal methods are synthesized largely from published sources [Bechtel; Black and Veatch; Brown and Caldwell; Culp, Wesner and Culp; and Webb]. Most processes considered were not designed for, nor widely utilized with dairy wastes. Process design modifications and corresponding cost adjustments, therefore, were modeled after consultation with Tchobanoglous to assure overall process applicability, effectiveness, and economy. The resultant annual cost estimates were then allocated to participating dairies on a per cow user cost basis.

Both direct disposal and treatment prior to disposal were evaluated initially. Although direct disposal is less complex, it is not necessarily more efficient. Processing waste prior to disposal offers three distinct advantages; volume reduction, waste stabilization, and resource recovery. Volume reduction may reduce waste management costs because transportation and disposal costs are a direct function of waste volume. Stabilization involves the physical, chemical, or biological degradation of raw waste such that the waste constituents causing deleterious environmental impacts are reduced. Resource recovery and utilization of dairy waste, like nutrient and energy recovery, offers the potential to off-set waste management costs.

After screening numerous alternatives, four regional waste treatment processes were selected for analysis as having "good" capabilities for volume reduction, stabilization, and resource recovery. Three of these (composting, anaerobic digestion, and refeeding) are "biological" processes while the fourth (incineration) is a "physical/chemical" process. A brief description of each process follows.

1. Composting is a biological process that partially stabilizes the organic content of raw waste prior to land application. Volume reduction, concentration of plant nutrients, and increased water holding capacity are characteristics of composted manure. Commercial composting operations in the Chino Basin have been an effective waste management alternative. But poor market development limits wide-spread adoption of composting. Currently, about 20 percent of the manure in the Chino Basin is hauled to compost companies [Webb]. In light of dim prospects for future market development, we assume that no more than 20 percent of the dried manure will be composted. We further assume that composting incurs no off-dairy costs, consistent with existing market conditions in the Chino Basin.

2. Refeeding manure to animals offers a promising new extension of material recovery. Most of the original nutrients available in dairy rations are not digested by the cows. Processing the manure can enhance the nutritional value of feed by increasing both the availability and concentration of protein and energy. Processing also removes hazardous substances such as heavy metals, pesticides, drugs, and pathogens that may be in the manure. Three basic technologies for manure refeeding are available, but only one was evaluated because of plans for constructing a pilot plant in the study area. This process is termed "Refeed."

3. Anaerobic digestion is a liquid waste treatment process that biologically stabilizes organic matter in the absence of oxygen. Methane gas, produced during organic degradation and stabilization, can be recovered and utilized as an energy source. Anaerobic treatment methods are either unmanaged anaerobic lagoons (common to livestock operations) or controlled complete-mixed reactors (common to municipal treatment). Un-

managed lagoons tend to serve as little more than holding ponds, whereas temperature and mixing are controlled to promote optimum conversion and production of methane in this latter system. Thus, complete-mixed reactors are investigated here. The impacts of two loading rates on process cost and performance are investigated: 0.2 and 0.4 pounds of volatile solids per cubic foot.

4. Incineration is a process of burning combustible matter under controlled conditions. Although the process was originally designed to reduce waste to an inert state, waste-heat recovery has become an important design consideration to capture energy contained in the waste. Both conventional refractory wall incinerators and waterwall incinerators are used for heat recovery. However, only waterwall units are evaluated here because of their reduced volumetric capacity and less specialized equipment required to control air pollution from exhaust gases and particulate matter.

Only in the material recovery processes — composting and refeeding — are the recovered by-products in final consumption form. In contrast, the liquid and thermal processes — anaerobic digestion and incineration — require additional conversion to produce the final product. The cost of by-product recovery equipment is included for these latter processes in which steam and gas are converted to electricity, put into the existing electrical grid, and sold to the local power company at a conservatively estimated wholesale price of $.02/kwh. Composting, however, is assumed to generate no revenue for the dairy operation, reflecting the existing market conditions in the Chino Basin. No well-defined market data were available to serve as a basis for estimating the value of material recovered from the Refeed Process. Thus, alternative cost-revenue situations (10 percent loss, breakeven, and 10 percent profit) were used to evaluate a range of process performance levels.

Each treatment method except composting requires disposal of some residual. Sanitary landfilling and marine discharge of processed effluent were evaluated as potential disposal methods. However, only sanitary landfilling may be used for disposal without prior processing. Spreading manure on dairy-owned or controlled pasture was also considered as a direct disposal method, but regional water quality standards limit the loading rate to about 7.5 percent of the 1976 Chino Basin dairy population of 167,000 cows. However, no off-dairy costs are incurred from the limited spreading option.

Waste transport functions differ for liquid and solid waste treatment/disposal processes. Transportation costs for solid materials are estimated for 10 ton trucks which are the conventional sized vehicles presently used by Chino Basin manure haulers, and for 24 ton trucks which are standard size longhaul vehicles. Transportation costs corresponding to anaerobic digestion were estimated for a gravity flow, liquid conveyance system (sewer).

Step Two: The Systems Approach

Assurance of overall long-run production efficiency in the integrated dairy production and waste management system is the goal of the systems approach. Accordingly, this step involves derivation of: 1) efficient dairy production systems exclusive of waste management, and 2) on-dairy adjustments necessary for harmonious integration of dairy production and waste management. The economic-engineering approach developed by French, Sammett, and Bressler, and outlined by French provided the methodological basis. Model dairies were disaggregated into four technical stages of production coordinated by management: milking, housing, feeding, and waste management. Detailed input-output relationships were specified for all relevant technologies within the first three stages, and combined into various sizes of model dairies ranging from 375 to 1200 cows. A short-run cost function was synthesized for each model dairy by aggregating the required quantities of fixed and variable inputs with their respective market prices. The long-run average cost

curve, specified on a per cow basis, was then formed as a discontinuous aggregation of short-run average cost curves for each model dairy. Detailed discussion of economies of size in dairy production and the analytical results for the first three production stages is presented in Matulich and Matulich, Carman, and Carter.

On-dairy waste collection plus modifications to the dairy production system commensurate with the alternative treatment and disposal processes are analyzed in a fashion similar to the first three stages of dairying. Requisite on-dairy adjustments are engineered and cost estimates developed. The resultant per cow cost estimates are added to those of the first three dairy production stages plus the waste transportation, treatment, and disposal user-cost estimates. The systems approach process ranking is then established by comparing composite unit costs among all waste treatment/disposal processes.

Findings, Step One

Annual off-dairy costs, net of recovery revenues are shown in Table 1. The estimates include all transportation, treatment, recovery, and disposal costs for each method. While most cost estimates were developed originally for process capacities ranging from 1500 cows to 167,000 cows, the estimates presented in Table 1 approximately reflect basin-wide capacities. The maximum scale economies are captured at this size [Matulich, Carman, and Carter]. The Refeed Process is an exception due to its construction in modular 10,000 cow capacity units. Consequently, cost estimates were developed under two capacity assumptions: approximately one-half of all basin manures are processed and all basin manures are processed. These capacities are denoted in Table 1 as "Refeed 80,000" and "Refeed 160,000", respectively. Cost estimates for both Refeed size designations are presented for the three material recovery price assumptions — a 10 percent profit, break-even, or a 10 percent loss.

Unit costs for several of the waste management methods listed in Table 1 are reduced by managing wastes in combination with the limited spreading and composting options that incur no off-dairy costs. Additional unit cost reductions are achieved for the two Refeed systems by eliminating under-utilized capacity in the last modular plant.

Minimizing waste treatment/disposal costs (including transportation), but without regard for the dairy production system, yields user costs ranging from a net revenue of $2.87 per cow to a net cost of $26.53 per cow. Thus, the Refeed 160,000 system would be selected as least cost.

Findings, Step Two

Successful integration of the waste management stage with the overall dairy production system is based upon the process of dairy waste generation. Feed, drinking water, and wash water are transformed into waste products during the feeding, housing, and milking stages. The final quantity and composition of waste flows requiring treatment, disposal, or both are determined by these production stages. Opportunities to affect waste generation exist at each stage, but in all likelihood are not equally effective focal points for waste management. The most important focal point for integrating the waste management stage into the overall dairy production system is the housing stage. The housing stage offers the opportunity to control weather-induced waste flows (runoff) and more importantly, to accommodate the waste collection function. Thus, the housing stage was emphasized in this study.

Two types of dairy housing were examined; free stall with adjacent corral and dry lot corral. For a description of housing types, see Matulich, Carman, and Carter. The flow of waste to ultimate disposition, as shown in Figure 1, differs by housing type. Free stall housing permits both solid and liquid treatment/disposal methods whereas dry lot housing permits mainly solid waste practices.

TABLE 1. Total and Per Cow Annual Costs Net of By-Product Recovery Revenues for Alternative Off-Dairy Waste Management Processes

Process			Total net annual	Net annual per cow cost[a]
			thousand dollars	dollars
Refeed	160,000	(profit)[b]	− 480[c]	− 2.87[c]
	80,000	(profit)[b]	220	1.32
	160,000	(breakeven)[b]	384	2.30
	80,000	(breakeven)[b]	752	4.50
Incineration			875	5.24
Refeed	80,000	(loss)[b]	1,184	7.09
	160,000	(loss)[b]	1,248	7.47
Sanitary landfill		(24 ton truck)[d]	2,200	13.17
		(10 ton truck)[d]	3,200	19.16
Anaerobic digestion		(0.4 loading rate)	4,200	25.15
		(0.2 loading rate)	4,430	26.53

[a] In order to compute user costs on a per cow basis, various unit-cost reducing combinations were used. The Refeed system combines Refeed and spreading for the 160,000 cow capacity and Refeed, disposal, composting, and spreading for the 80,000 cow capacity. The incineration system combines with composting and spreading.

[b] Profit, breakeven and loss refer to the alternative materials recovery price assumptions employed for the Refeed Process.

[c] The Refeed 160,000 system under the 10% profit assumption realizes a net revenue as indicated by the minus sign.

[d] Haul distance for the sanitary landfilling option is assumed to be 30 miles round trip.

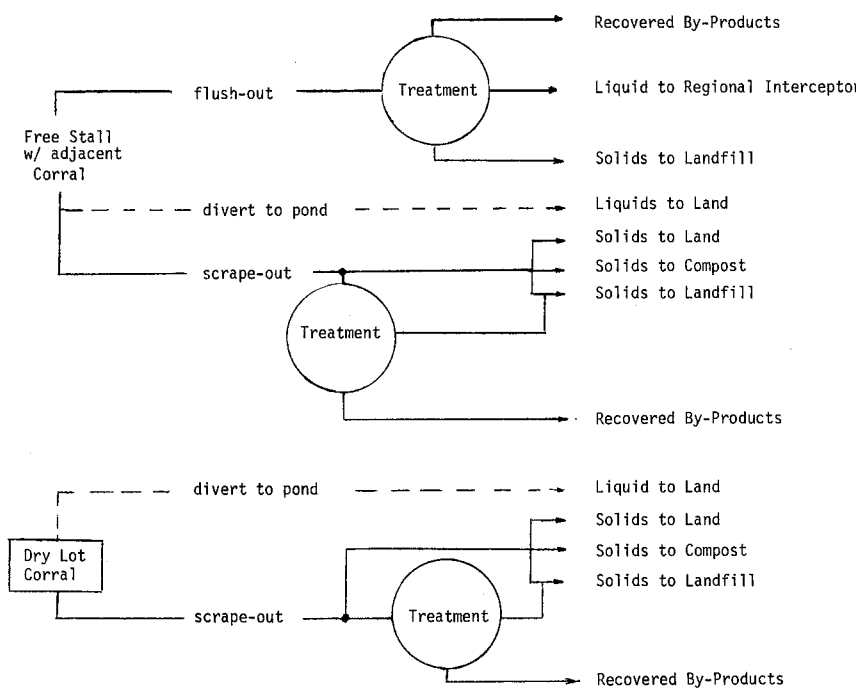

Figure 1. General dairy waste flows to ultimate disposition, by housing type.

Incineration, composting, sanitary landfilling, and spreading all utilize naturally dried manure deposited on the corral surface which is allowed to accumulate 6 months prior to collection. The manure is then transported directly to disposal or to treatment prior to disposal. Estimates of corral cleaning charges were developed from a survey of the major commercial corral cleaners and manure haulers serving the Chino dairy community. Charges averaged $1.00 to $1.20 per ton of manure removed. Assuming 3.65 tons of corral scraped manure per cow per year and a cleaning charge of $1.10 per ton, the annual on-dairy collection costs total approximately $4.00 per cow. No adjustments or modifications in housing design are required for these four treatment/disposal methods.

In contrast, the Refeed Process requires on-dairy adjustments. Housing type is critical since only fresh manure deposited on concrete is utilized in the Refeed Process. Virtually all the manure is collected on concrete with free stall housing, whereas at most one-half the manure is captured on concrete with modified dry lot housing. These proportions are consistent with the amount of basin-wide manures processed under the Refeed 160,000 and 80,000 systems. Therefore, free stall and dry lot housing combine with the Refeed 160,000 and 80,000 systems, respectively. Under the free stall-Refeed 160,000 system, additional labor required for daily alley scraping is estimated to increase annual labor costs by $320 per free stall housing unit. Furthermore, a bunker with seven day manure storage capacity must be constructed. Bunker construction costs were estimated for two herd ranges: $11,000 for herds between 375 and 750 cows and $19,000 for herds between 750 and 1,200 cows. On an annual basis, assuming a 20 year life and a nine percent interest rate, bunker costs are estimated to be $1,205 and $1,971, respectively.

The small quantity of concrete in dry lot housing poses a special managerial problem for the Refeed 80,000 system. The cow alley must be modified to increase the time cows stand near the feed in order to capture one-half of the wastes on concrete [Chang, Adriano, and Pratt]. Modifications involve widening the cow alley by two feet, and placing a fence behind the cow alley with gates at either end. Additional annual alley costs for each 100 and 120 cow corral are $160 and $182, respectively. A bunker with seven day waste storage capacity is necessary, but because only one-half of the manure is deposited in the modified alleys, bunker costs are one-half of those of free stall housing. Annual bunker costs, therefore, are $603 for herds of 375 to 750 cows and $986 for 750 to 1200 cows. Additional labor to scrape out the alley amounts to 60 hours or $213 per corral per year. Besides these on-dairy adjustments to support the Refeed 80,000 system, the remainder of the manure must be removed from the earthen loafing area. The associated on-dairy practice is the same as that already discussed under incineration, sanitary landfilling, composting, and spreading, but the cost per cow is halved since only half as much manure is collected. The naturally dried manure is collected by commercial corral cleaners at an annual cost of $2.00 per cow.

Anaerobic digestion of dairy waste requires flush-out waste collection coincident with free stall housing. Water recovered from cow and parlor washing and from refrigeration is released periodically to flush manure from the housing area. Substantial housing modifications are necessary, but in contrast with scrape-out collection, no labor is involved. Specific modifications to free stall housing depend upon the flushing technique. The flush-out cost estimates developed here generalize various dairy-specific solutions, and are considered to be representative averages. Flush-out collection system costs, including water collection and impoundment, delivery lines, footings, valves, and other necessary equipment and facility adjustments, were estimated at $2,000 per free stall housing unit. Assuming a 20 year life and a 9 percent interest rate, annual cost per free stall housing unit is $219.

Short-run average costs for the integrated

dairy production and regional waste management systems are presented in Table 2. Unit costs per cow are summarized by milking parlor configuration and housing type. Each of the unit cost entries represents composite least cost configurations for each dairy size class corresponding to the alternative waste treatment and disposal techniques. Comparison of costs for each dairy design capacity reveals that the waste management process rankings differ from those in Table 1 where treatment/disposal costs were minimized irrespective of dairy production considerations. Under the integrated systems approach to waste management, the Refeed 160,000 system (breakeven assumption) moves from first position to fourth; the Refeed 80,000 system (breakeven assumption) remains second; incineration moves from third to first; sanitary landfilling moves up to third; and anaerobic digestion remains fifth. The alternative Refeed Process price assumptions of a 10 percent profit or a 10 percent loss were found to leave the relative ranking essentially unchanged [Matulich, Carman and Carter].

The cost differential between dry lot and free stall housing is largely responsible for the ranking change, as well as the invariance of process ranking across herd sizes. Unit costs of free stall dairies average $25 to $30 more per cow than do dry lot dairies. In light of the dominant role housing plays in determining the applicability of a particular treatment/disposal process, and in consideration of additional on-dairy modifications, the sys-

TABLE 2. Short-Run Average Costs of Integrated Dairy Production and Regional Waste Management Systems for Least Cost Dairies at Capacity: By Herd Size, Milking Parlor and Waste Management System, California, 1975[a]

			Dry Lot			Free Stall	
Herd size	Parlor[c]	Housing size	Incineration	Refeed 80,000[b]	Sanitary Landfill	Refeed 160,000[b]	Anaerobic digestion
			---------- dollars per cow ----------			------ dollars per cow------	
375	H_{5S}	100	1,065	1,068	1,073	1,098	1,116
400	H_{5S}	80	--	--	--	1,089	1,106
450	SO_{3-2}	120	1,024	1,026	1,032	1,057	1,076
500	SO_{3-2}	100	1,041	1,043	1,049	1,073	1,090
600	SO_{3-2}	120	1,019	1,021	1,027	1,050	1,069
625	SO_{3-2}	100	1,019	1,022	1,027	1,053	1,073
700	SO_{4-2}	80	--	--	--	1,039	1,059
750	SO_{4-2}	100	1,001	1,003	1,009	1,033	1,053
875	H_{10C}	100	1,114	1,116	1,122	1,144	1,164
900	H_{12A}	120	1,002	1,004	1,010	1,035	1,055
1,000	H_{10A}	100	1,010	1,012	1,018	1,039	1,059
1,050	H_{12A}	120	1,009	1,011	1,017	1,039	1,060
1,125	H_{10C}	100	1,091	1,193	1,199	1,123	1,143
1,200	H_{16A}	120	999	1,001	1,007	1,028	1,049

[a] Marketing costs including licenses, association fees, quota charges, and milk hauling charges were omitted from this analysis.

[b] On-dairy adjustments associated with the Refeed Process depend on the proportion of basin wastes processed by this method. Two capacities are modeled, 160,000 cows which would satisfy off-dairy treatment/disposal requirements for the basin and 80,000 cows which is about one-half of total treatment/disposal requirements.

[c] H_{5S} Double 5 Herringbone parlor with swinging machines.
H_{10C} Double 10 Herringbone parlor with conventional machines.
H_{10A} Double 10 Herringbone parlor with automated machines.
H_{12A} Double 12 Herringbone parlor with automated machines.
H_{16A} Double 16 Herringbone parlor with automated machines.
SO_{3-2} Double 3 Side-Opening parlor with automated machines and a wash stall.
SO_{4-2} Double 4 Side-Opening parlor with automated machines and a wash stall.

tems approach to dairy waste management appears critical to assurance of overall long-run production efficiency. If waste treatment and disposal costs are minimized and simply added-on to the dairy as in the step-one procedures above, then a suboptimal overall system likely would result.

Conclusions and Implications

Increasingly stringent environmental quality regulations place severe economic pressures upon agriculture. Producers must manage wastes in compliance with environmental regulations while still attempting to maintain overall production efficiency. Traditional approaches to analyzing waste management that focus only on the immediate problems of compliance make waste management appear synonomous with treatment and disposal. The results of this study demonstrate that waste management should not be regarded as a separable stage of production; such a short-sighted approach may promote suboptimal decisions based solely upon minimizing the cost of waste treatment/disposal. Attempts to meet environmental quality regulations without consideration of interdependencies between waste management and agricultural production could compromise potential efficiencies in the overall system. Accordingly, the systems approach used here explicitly views waste management as an integral stage of large-scale dairy production.

The nature and extent of interactions between waste treatment/disposal and primary production must receive additional attention in the future. There are potential sources of interdependence in all stages of dairy production, but the interdependence of waste collection and the dairy cattle housing stage was the focal point of this analysis. Opportunities to alter or augment waste generation in the other stages of production may also impact the overall system design and economy. For example, feeding programs may some day have multiple objectives. Present concerns address only the efficient transformation of feed into milk. Resource recovery from animal waste may play an important role in feeding stage decisions concerned also with the quantity and composition of wastes.

The analysis further suggested that even the traditional application of production efficiency needs careful reconsideration when addressing agricultural waste management issues. While conventional wisdom suggests waste management to be a major source of diseconomies of size, the converse was found in this study. Economies in waste treatment/disposal were realized basin-wide that could not have been enjoyed by individual dairies. Concentration of the industry in the Chino Valley allows individual dairies to capture these collectively available scale economies. Adequate industry concentration, for example, appears necessary to hold down transportation costs in order to benefit fully from regional economies. Such regional considerations may continue to have important implication for the future organization of livestock production.

Opportunities for resource conservation and recovery through waste utilization are major benefits of large-scale treatment methods previously dismissed as uneconomical. Incineration, for example, is estimated to generate more than 5.6 million dollars worth of electricity annually, based upon a 1976 co-generation price of $.02/kwh. Since that time, power rates in the Los Angeles area have almost doubled. The potential impact of this rate change upon dairy waste management is profound. Electrical power generation revenues at $.02/kwh were estimated to offset all but one million dollars of the total annual incineration and disposal costs for the entire Chino dairy cattle population. By contrast, a price of $.04/kwh yields a net revenue of more than 4 million dollars per annum. Costs would equal power generation revenues at approximately 40,000 cows. In an era of escalating rate structures and uncertainty of power availability, energy recovery from animal waste may soon play a dominant role in the selection of waste management practices.

Opportunities to manage the waste from large scale confinement operations in a manner consistent with acceptable environmental quality do exist. However, large capital commitments to waste management will be necessary. Innovative and comprehensive management practices that recognize waste as an intentional joint product may be essential to the realization of an efficient agriculture.

References

Ashraf, M. and R. L. Christensen. "An Analysis of the Impact of Manure Disposal Regulations on Dairy Farms." *Amer. J. of Agri. Econ.* 56 (1974): 331-336.

Bechtel, Inc. *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems*. U.S. EPA, Washington, D.C., 1966.

Black and Veatch, Consulting Engineers. *Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities*. Water Pollution Control Research Series, U.S. EPA, 1971.

Brown and Caldwell, Consulting Engineers. *Solid Waste Management Resource Recovery Study*. Report prepared for the Central Contra Costa Sanitary District, San Francisco, California, 1974.

Chang, A. C., D. C. Adriano, and P. F. Pratt. "Waste Accumulation on a Selected Dairy Corral and Its Effect on the Nitrate and Salt of the Underlying Soil Strata." *J. of Env. Quality*, 2 (1973).

Culp, Wesner, and Culp, Clean Water Consultants. *Estimating the Costs of Wastewater Treatment Facilities*. Prepared for the Commonwealth of Virginia State Water Control Board, 1974.

French, B. C. "The Analysis of Productive Efficiency in Agricultural Marketing: Models, Methods, and Progress." *A Survey of Agricultural Economics Literature: Volume 1*. L. R. Martin (Editor), University of Minnesota Press, pp. 93-206, 1956.

French, B. C., L. L. Sammet, and R. G. Bressler. "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears." *Hilgardia* 24 (1956): 534-721.

Good, Darryl. "Potential Impact of Environmental Pollution Abatement Alternatives on the Michigan Dairy Farming Industry." Unpublished Ph.D. Thesis, Department of Agricultural Economics, Michigan State University, 1973.

Matulich, S. C., H. F. Carman and H. O. Carter. "Cost Size Relationships for Large-Scale Dairies with Emphasis on Waste Management." Giannini Foundation of Agricultural Economics Research Report No. 324, October, 1977.

Matulich, S. C. "Efficiencies in Large-Scale Dairying: Incentives for Future Structural Change." *Amer. J. of Agr. Econ.* 60 (1978): 624-647, 1978.

Tchobanoglous, G. T. Professor, Sanitary Engineering, University of California, Davis. Personal Communications, 1975 and 1976.

Webb, A. A., Associates, Consulting Engineers. *Dairy Waste Management*. Report for the Santa Ana Watershed Planning Agency.