MEASURING THE BENEFIT OF A COMPUTER IN THE MILKING PARLOR:
The Yavneh dairy case study

E. Gelb [a], Y. Kislev [b], H. Voet [b]
[a] Center for Agricultural Economic Research, Rehovot Israel gelb@agri.huji.ac.il
[b] Department of Agricultural Economics and Management, Faculty of Agriculture, Hebrew University, P.O.Box 12, Rehovot, Israel. <kislev@agri.huji.ac.il>; <voet@agri.huji.ac.il>

Abstract
This paper reports an experiment conducted to assess the contribution of a computer system in the milking parlor to the detection of mastitis and estrous (udder infection and the time to inseminate the cow). The experiment was carried out in a herd of 700 cows in Israel. It was found that the computer system contributed markedly to the cows' productivity and profitability.

(Key words: Computers in Agriculture, Dairy Economics, Management Information Systems, Milk Production, Mastitis, Estrous)

Acknowledgements
The authors thankfully acknowledge the cooperation of the Yavneh herdsmen, the Afimilk development team and the advice of Y. Yahav, O. Makusfeld-Nir, A. Saran, A. Berman and E. Ezra - generously offered throughout the study. Barbara Kohn read an earlier draft of the manuscript and made several important suggestions. The authors are of course solely responsible for remaining errors.

Funding for the study was provided by the Israeli Cattle Breeders Association, The Israeli Milk Marketing Board, the Ministry of Agriculture's fund for Promoting Innovations in Agriculture and a grant from the Brian Davidson Center for Agribusiness.

Introduction
The use of computers and innovative information technology in agriculture - including the application of sophisticated methodology such as georeferencing methods Lowenberg-DeBoer (1996) has been gaining ground. Even so the economic implications of these modern developments are seldom quantified. Particular advancements in the use of Information Technology were made in livestock husbandry as documented by Geers (1994) and Maatje et al. (1997). Following these developments several writers suggested approaches to economic analysis of the new technology. Examples are Dijkhuizen et al. (1997), Frost et al. (1997) and Verstegen et al. (1995) but only scant quantitative empirical analysis was offered. The studies that did attempt to quantify the impact of the new technology either analyzed the characteristics of the adopting farmers as described by Putler and Zilberman (1980), attempted to identify critical success factors and information needs as described by Huirne et al. (1997) or assessed the benefits by comparing the performance of farms with computerized information systems to those without. Examples are Verstegen et al. (1993) in pig production and Lazarus et al. (1990) and Van Asseldonk et al. (1998, 1999) in dairy. Agricultural scientists such as Allore et al. (1995) discussed the technical aspects and potential contribution of computer systems.

In this paper we report a direct measurement of the economic contribution of a computerized information system in dairy (the system that was installed was the Afimilk system). The study was conducted in a large dairy herd in kibbutz Yavneh, a communal farm in Israel. We focus on two major areas: mastitis detection and identification of estrous. Both occurrences are major and economically significant events in dairy herds requiring accurate identification and timely attention. The first - mastitis - is udder infection, estrous is the time the cow is in heat and ready for insemination. Nielen (1994) discusses in detail the benefits of early mastitis detection and treatment and the contribution of this factor to the value of an "automatic" detection system. Maatje et al. (1997) discuss the benefit of accurate estrous detection.

The paper opens with a short introductory discussion of mastitis, estrous and a computerized dairy Management Information System (MIS). The empirical core of the study is presented in the sections reporting the findings for the Yavneh herd analysis. The paper concludes with an economic estimate of the contribution of the computerized information system.

Mastitis - the disease and its importance

Mastitis is a generalized term for a wide range of udder infections. Mild cases cause short term loss of milk yield and reduction in its quality, but losses may be of long duration and in severe cases cows have to be culled. The infection may be and has been detected by visible symptoms, on sight. Early detection enables timely treatment, reducing or even preventing mastitis-related losses although on-sight detection and identification may be quite inaccurate.

For the duration of the infection, mastitis-affected cows are milked separately, usually by hand, and the milk discarded. In addition, after recuperation from the acute infection, normal yield levels are recovered only gradually. Accordingly, we distinguish between <u>direct</u> milk loss, reduced production and discarded milk for the duration of the mastitis incident; and <u>indirect</u> loss due to long term yield reduction. The combined loss of milk production is the major damage caused by mastitis in cows that do recover. Additional mastitis related losses include the cost of extra labor required to milk separately or by hand, medicine, if applied, and a penalty for low quality milk. Quality is affected if mastitis is not detected and milk from infected cows goes into the parlor's milk tank. One of the prime tasks of the dairy operator is to minimize these losses; early detection and accurate information on the affected cow's condition and history are crucial prerequisites. Computer-connected electronic devices measure and record the electrical conductivity of the milk; mastitis is then indicated by deviations from normal conductivity. These deviations are usually identified before the observation of visible symptoms.

Estrous, background

Estrous is the period of heat. Accurate detection and consequent insemination increase the probability of timely and successful conception. Most cows in Estrous can be detected by visible symptoms: unrest, mounting and vaginal discharge. These cows are examined, inseminated if found to be in heat. Success was verified after 28 days by testing for progesteron in the milk. Others may not display visible signs of heat - this is an anestrous condition. In these cases the cows are inspected by the veterinarian to determine estrous or the cause of its absence. Unidentified estrous reduces the probability of timely insemination, increases the number of unintended and unproductive open days (days between calving) and may result in culling of high yielding cows.

Computer-supported activity-measurements are used for identification of estrous. Cows within the Afimilk system wear foot tags with pedometers that identify them in the milking stall. The pedometers count steps per time unit, the numbers are transmitted to the information system and the hourly averages recorded. Deviations from each cow's norm are marked as unrest, suspected estrous and possible ill health. The Afimilk system installed in kibbutz Yavneh at the time of the study could indicate estrous in cows that had calved at least once, modern systems such as those described by Maatje et al. (1997) can detect estrous in calves before first calving as well.

The Afimilk System

Afimilk is the trade name of the dairy parlor information system used in this study. It is partly produced and assembled in Israel. Such systems include a PC and electronic devices which identify cows, monitor their production variables, keep records and provide management with information to assist in making feeding, health and reproduction decisions. Afimilk was first introduced experimentally in 1986 and by now, more than 65% of the large herds in the country have installed the system. Two other computerized systems are used in a small number of herds in Israel. Afimilk performs the following functions:

1. identifies cows in the milking stalls;
2. monitors the cow's milk flow and yield;
3. measures electrical conductivity of milk and indicates suspected mastitis;
4. records unrest and indicates estrous.

The system features, three times daily, irregularities, deviations and detection alerts. Data summaries are constantly on call as are specific reports – such as individual cow's health and yield history. Parameters for significance levels of tests of deviations can be fine-tuned by season, group or cows' conditions. It may be added that in measuring the economic benefits of the functions the Afimilk system performs we are not trying to evaluate it's technical efficiency or compare it to alternative commercial systems.

The experiment domain

Kibbutz Yavneh, where the study was conducted, is located on the coastal plain in Israel. The kibbutz operates several farm enterprises, among them a dairy of close to 700 cows. Milk production is controlled in Israel by the Milk Marketing Board and paid a regulated price (with premiums for quality and penalties for substandard milk). Milking is done three times a day and yields in Yavneh are relatively high; at the time of the study the yield was above 10,000 kg per cow, averaging 32 kg per day for an average 305 day lactation. Yavneh's previous dairy parlor computer system was changed to Afimilk in June 1993 when the study began. For the dairy team, experienced with the former system, the transition was smooth (it took one week) with no significant changes in management and decision procedures. The team was professional, highly qualified and cooperated willingly with the project.

The milking cows were divided with the introduction of Afimilk and the commencement of the study into a trial group and a control group. The information provided by Afimilk and used for mastitis and estrous detection was made available to the dairy operators only for the trial group. The information for the control group was blocked at source. Consequently, the herdsmen received only three yield measurements per day for the control cows, whereas additional 9 measurements were available for the cows in the trial group (steps per hour, rate of milk flow and electrical conductivity of the milk for each of the three milking sessions). Without this additional information the operators had to rely, in the control group, on conventional methods of mastitis and estrous detection. The cows from both groups were mixed in the cowsheds, group identity was masked and all cows were treated similarly.

The field study lasted 18 months, from June 1993 until December 1994. This period covered a full lactation period for all cows included in the study. Each cow's milk yield and other parameters were measured and recorded three times a day. For cows that had mastitis, direct daily milk loss was calculated from the day of detection until the cow was considered mastitis-free. The loss was calculated as the difference between the average daily yield of the 4 days before mastitis detection and the actual daily measurement from the time infection was confirmed. The magnitude of the indirect loss is difficult, if at all possible, to estimate for individual cows. We estimated the indirect loss by differences within the groups (trial and control) between the average yield of the infected and that of the uninfected cows. The effect of estrous detection was measured in open days (the days between calving and confirmed conception). The contribution of the Afimilk system was calculated as the value of the difference in milk production and average open days between the trial and the control groups of cows.
Although the Yavneh herd could be taken as the universe of the study population, statistical significance is reported as if the measured magnitudes were a random sample from the national herd (or a single year from a yearly time series of the Yavneh herd).[1] This makes for stricter evaluation of the results.

The division of the herd

The milking cows in Yavneh were divided into trial and control groups. Cows about to be culled were not included in the study. The selection was stratified by the following variables: lactation, calving related diseases, number of days from calving and projected milk yield. The stratification was lexicographic; that is, the cows were assigned into one of three categories by lactation - first, second or higher; each of these was divided again for calving related diseases - yes or no - thereby adding two categories for a total of 6. The assignment was then repeated within each category into an additional six categories by days counted from last calving. The process ended with the cows in each of these 36 strata being randomly divided between 303 cows in each group.

Mastitis detection

The total number of mastitis incidents during the time of the study was 316; of these, 116 were in the control group and 200 in the trial group (Table 1, in which, note, all the differences between the groups are statistically significant). These incidents occurred in 170 cows; some cows suffered from infection more than once during the period of the study while others did not show mastitis symptoms at all. Such differences can be expected, certain cows are more inclined to develop mastitis than others; but as our analysis was concerned with detection, we regarded each detected incidence as a separate independent realization, whether such incidents occurred once or several times for the same cow. Assuming that the groups did not differ systematically (an assumption to be corroborated by findings below), the larger number of correctly identified cases in the trial group indicates that the computer-supported detection system was more accurate than on sight detection.

Not all the incidents were included in the statistical analysis to follow. Cows in the first 10 days of milking as well as cows in the last 5 days of their lactation were excluded since it was impossible to estimate the yield effect of mastitis in these stages. Incidents which lasted less than 24 hours were also not included. Deleting these cases, 220 incidents were analyzed, 90 in the

[1] With centrally coordinated artificial insemination, average genetic yield potentials of all herds are essentially identical. Individual cows (phenotypes) naturally vary in performance. Differences between herds are also substantial, probably due to management and local conditions.

control and 130 in the trial group. The mastitis detection rate for the study control group was later found to be consistent with the general "computerized" mastitis detection rate of the Yavneh herd after the information masking was relaxed when the study ended. The average number of mastitis cases being treated simultaneously was usually less than three and the affected milk was not sent to market. In fact the Yavneh herd earned a premium for high quality milk - an additional income - which was not included in the calculation of the system's indirect benefit calculations.

Table 1 reports two additional statistics: the average duration of incident in the control group was 4.4 days as against 3.9 days for the trial group. Electronic monitoring both assisted in early detection and flagged comparatively light cases that might have gone unnoticed. Early detection leads to immediate treatment, where necessary, and a shorter incident duration. An additional benefit was that medical treatment, when applied, was less intensive.

Table 1. Mastitis detection

n = 606	Total	Control	Trial	Stat. sig.*
Number of mastitis infected cows	170	74	96	P<0.05
Number of incidents	316	116	200	P<0.05
Number of analyzed incidents of these the average	220	90	130	P<0.05
mastitis incident duration		4.4	3.9	P<0.05
% of medically treated incidents		86.6	78.5	P<0.05

Comparisons between incidence in the two groups were performed by the chi square test.

In Table 2 we divide the incidents by length and report direct milk loss (yield loss from the period of infection). Consistently with the shorter average duration reported in Table 1, there were more short term incidents (2-3 days) in the trial than in the control group and fewer long term cases. The differences in milk loss per day were not significant but the overall losses per incident - 65.1 kg per cow in the control and 44.8 in the trial group - were significantly different from each other.[2]

[2] Not all mastitis cases were cured. The prevailing policy was to cull cows that were not cured within 10 days. Accordingly, two trial and four control cows were culled. They were included in Table 2 in the 6-10 days category. Three other cows in the trial group were treated as special cases. These were high yielding cows that, following severe mastitis and early detection and medical treatment, the Yavneh team decided to save and left them in the herd for longer periods: 12, 13, and 18 days. Their average direct milk loss was 352 kg. They were not culled, but being special cases, were not included in the report of Table 2. In addition, 6 cows from the trial group and 14 from the control were culled due to low yield.

Table 2: Mastitis incident duration and direct yield reduction

n = 217	Number of incidents			Average loss per incident kg/cow		Average daily production	Stat. sig.*
Incident duration	Total	Trial	Control	Trial	Control	Difference	
2-3 days	108	70	38	21.3	24.6	1.32	n.s.
4-5 days	65	37	28	28	61.3	0.86	n.s.
6-10 days	44	20	24	103.9	133.6	3.71	n.s.
Average loss per incident		control 65.1± 52.9		trial 44.8 ±10	P<0.05		

Note: milk loss is in kg per cow.

Comparisons of loss between the two groups were performed by the t-test. n.s. is p>0.05

In Table 3 we report milk yield. The reporting is by group and sub-group: trial and control groups, cows with mastitis and cows without, and within the groups by length of lactation. For example cows that were milked more than 270 days DIM (Days In Milk) but less than 305 DIM were grouped under the 270 DIM heading, cows with more than 305 days of milking were grouped under the 305 DIM heading. Cows that did not reach 270 DIM were not included in the loss estimates of Table 3. For comparison, the lactation yield of a cow was taken as it's lactation for the indicated days**.** Since the comparisons are for the lactation periods, differences between the groups reflect both direct and indirect milk losses. For example, the yield for the first 270 days was taken for the cows at the 270 DIM checkpoint and not the total amount of milk they gave for the whole length of the period of lactation. As indicated earlier, the loss estimates were prepared at the group and sub-group level. The numbers in Table 3 are averages per cow in group for the lactation yield; for example, there were 29 cows with mastitis in the trial group with 305 DIM with an average sub-group yield of 10,896 kg milk per cow; similarly, 21 cows with mastitis in the control group yielded an average for 305 DIM of 10,387 kg per cow.

Table 3: Comparison of yields by Days in Milk - DIM (kg per cow)

n = 606	Less than 270 DIM	Average in herd		Cows without mastitis		Cows with mastitis	
Lactation days		270	305	270	305	270	305
Trial group, yield		9270	10606	9184	10513	9661	10896
Number of cows	28	156	119	128	90	28	29
Stand. Dev.		±1090	±1425	±1061	±1499	±1154	±1140
Control group, yield		9075	10289	9121	10290	8835	10387
Number of cows	39	152	112	127	88	25	21
Stand. Dev.		±1248	±1182	±1258	±1236	±1185	±981
Yield difference in trial's favor		195	317	63	223	826	509
Stat. Signif.*		n.s	P<0.05	n.s	n.s.	P<0.05	P<0.05

Comparisons of differences between the two groups were performed by the t-test. n.s. is p>0.05

Several points are worth noting. Yields of cows "without mastitis" in the trial and control were not significantly different, which is not surprising - the Yavneh herd was divided into groups of similar average yield potential and yield affecting history. The yield differences, for cows with detected mastitis, between the trial and control groups were statistically significant. Note also, that for the four comparisons (trial and control, 270 and 305 DIM), the yield of most of the mastitis infected cows was equal or higher than for the non-infected: high-yielding cows are comparatively more susceptible to infection. Houben et al. (1993), Nielen (1994) and Lucy and Rowlands (1994) report similar findings. (An exception are the 270 DIM cows in the control group: perhaps due to delayed detection and longer duration of mastitis the diseased cows recorded lower average yields than the "without" cows). The findings reported in Table 3 data will be used in the economic analysis.

Estrous detection

Table 4 summarizes the major findings for the 352 cows that fitted into the study's 18 months schedule and with pregnancies of less than 150 open days. Delayed impregnation - defined as having more than 150 open days - is usually caused by problems unrelated to inaccurate estrous detection such as reproductive system malfunction and diet deficiency disorders. These pregnancies and the explanation of their greater open day differences are beyond the scope of this study.

Table 4: Conception rates and open days

N=352	Control	Trial	Difference	Stat. sig.*
Number of cows	180	172	8	
% examined for anestrous before insemination	35.5	20.3		P<0.05
Conception rate (%)	31.5	31.5	-	
Pregnancies with <150 open days (%)	111 (61.6)	125 (72.6)	14	p<0.05
Average open days ± (s.d.)	114.3 ± 48.0	111.1 ± 52.5	3.2	n.s.

Comparisons of differences between the two groups were performed by the by the chi square test.

As the data in Table 4 indicates, there was no difference in the conception rate between the trial and the control groups, it was 31.5% for each group. Once estrous was detected and the cows inseminated, control and trial cows reacted in the same way. There were however significant differences in anestrous cases (cases in which heat was not detected but estrous suspected by day counting and progesterone testing) and in the number of open days. By both measures, cows in the trial group, with 20.3% anestrous and 111.1 open days, did better than those in the control group. We have also found, but not reported in Table 4, that the differences between the trial and the control groups increased with age. It is more difficult to detect estrous in older cows and the electronic devices therefore contribute more to estrous detection as the cows age.

Benefits and costs

Computer detection reduced milk losses due to mastitis and open days of milking cows. The calculation of the benefits in our experiment was based on data prepared by the Extension Service of the Ministry of Agriculture converted to US dollars at the prevailing rate of the study time, 3.02 NIS per dollar. The following parameters are from Rosen and Yechieli (1995):

Gate price of 1 kg standard quality milk	$0.36
Marginal feed cost	$0.10
Marginal net value of 1 kg. milk	$0.26
Value of open day prevented	$3.14

Production in Yavneh dairy is under quota restrictions and therefore the gain from mastitis prevention is measured in terms of feed saved (see Appendix A.)

Table 5 reports the benefits per cow in the herd in Yavneh. Milk loss prevented, 248 kg, was calculated as the weighted average for yield difference in trial's favor in Table 3 (for average in herd). The number for average open days is from Table 4. The sum of benefits per cow is $34.85. The information generating equipment needed to perform the tasks we considered - mastitis identification and estrous detection - is optional, it may be added to the basic equipment in the milking parlor and milk recording facilities. In Yavneh, the investment for the additional equipment was $200 per cow (it would be markedly lower today). This includes foot tags, milk meters, data transmission components, monitoring equipment, installation and setup. The repayment period is therefore about 6 - 7 years.

Table 5: Gross benefits (average per trial cow in herd)

	Measured benefits	Measured differences*
Prevented milk loss	$24.80 = ($0.10*248)	248 kg
Reduced open days	$10.05 = ($3.14*3.2)	3.2 days
Total benefits	$34.85	

*Measured differences are from Table 3 and Table 4

Concluding remarks

We have reported an experiment in one herd. The findings clearly indicate a favorable cost-benefit ratio, even if the system would last in the milking parlor for only a few years, as so often happens with computer - embedded modern equipment. Several comments are now in order.

The cost of the system - per cow - will be higher for smaller herds. The benefits, on the other hand, could increase with herd size because of the difficulty to recognize individual cows and monitor their particular problems. Kibbutz herds are relatively large. The benefit from such a system may be different for family farms with 30 - 50 cows.

The human factor is of great importance in livestock enterprises, and Yavneh, as indicated, has a dedicated group of workers - professional and motivated. It may well be that the contribution of the computer system would have been greater with an average team. Particularly, one may expect the share of the contribution of estrous identification to be larger in many other dairies. Also, it is often claimed that the benefits of a computer system should be attributed to improved management practices by teaching operators the significance of even minor nuances in livestock behavior and performance and reporting them. This component was probably only of minor importance in Yavneh and, still, as our findings indicate, the computer system contributed substantially to profitability of milk production in the kibbutz.

We attributed benefits only to losses prevented in milk and open days. These are not the only benefits; for example, early detection of mastitis and accurate identification of estrous may reduce culling of problematic, often high-yielding, cows. We similarly did not include in the benefits the prevention of discarded milk of mastitis infected cows, of additional labor needed for milking an infected udder by hand and the cost of medicine prevented.

REFERENCES

Allore, H., Jones, L., Merrill, W., and Oltenacu, P., 1995. A Decision Support System for evaluating Mastitis information. Journal of Dairy Science, 78:1382 -1398.

Dijkhuizen, A. A., Huirne, R. B. M., Harsh, S. B. and Gardner, R. W., 1997. Economics of robot application. Computers and Electronics in Agriculture, 17:111-121.

Frost, A. R., Schofield, C. P., Beaulah, S. A., Mottram, T. T., Lines, J. A. and Wathes, C. M., 1997.

A review of livestock monitoring and the need for integrated systems. Computers and Electronics in Agriculture, 17:139-159.

Geers, R., 1994. Electronic monitoring of farm animals: a review of research and development requirements and expected benefits. Computers and Electronics in Agriculture, 10:1-9.

Houben, E., Dijkhuizen, A., Arendonk, J. and Huirne, R.B.M., 1993. Short and long term production losses and repeatability of Clinical Mastitis in Dairy Cattle. Journal of Dairy Science, 76:2561-78.

Huirne, R.B.M., Harsh, S. B., Dijkhuizen, A.A., 1997. Critical Success Factors and Information needs on dairy farms: The Farmer's opinion. Livestock Production Science, 48: 229-238.

Lazarus, W., Streeter, D. and Joffre-Giraudo, E., 1990. Management Information Systems: impact on dairy farm profitability. North Central Journal of Agricultural Economics, 2:267-277.

Lowenberg-DeBoer, J., 1996. Precision Farming and the new Information Technology: Implications for farm management, Policy, and Research: Discussion. American Journal of Agricultural Economics, 78:1281 -1284.

Lucy, S. and Rowlands, G., 1994. The association between clinical mastitis and milk yield in dairy cows. Animal production, *39:165*-75.

Maatje, K., de Mol, R. M. and Rossing, W., 1997. Cow status monitoring (health and estrous) using detection sensors. Computers and Electronics in Agriculture, 16:245-254.

Nielen, M., 1994. Detection of bovine mastitis based on milking parlor data. Ph.D. Thesis, Faculty of Engineering, Utrecht University, The Netherlands.

Putler, D. and Zilberman, D., 1980. Computer use in agriculture: evidence from Tulare county, California. American Journal of Agricultural Economics. 70:790-802.

Rosen, S., and Yechieli, Y.,1995. An evaluation of the selection process in dairy herds. The Israeli Cattle Breeders Association Monthly, 254:41-43 (Hebrew).

Van Asseldonk, M.A.P.M., Huirne, R.B.M., Dijkhuizen, A.A., Tomaszewski, M.A. and Harbers, A.G.F., 1998. Effects of Information Technology on dairy farms: an empirical analysis of milk production records. Journal of Dairy Science, 81:2752-2759.

Van Asseldonk, M.A.P.M., 1999. Economic evaluation of Information Technology applications on dairy farms. Ph.D. Thesis. Department of Farm Economics and Management. Wageningen Agricultural University, The Netherlands.

Verstegen, J. A. A. M., Hurne, R. B. M., Dijkhuizen, A. A. and Kleijnen, J. P. C., 1995. Economic value of Management Information Systems in agriculture: a review of evaluation approaches. Computers and Electronics in Agriculture, 13:273-288.

Appendix A: Production under Quota

Consider a herd of M cows, each fed X units of feed per year at the cost of c dollars per unit. Annual milk yield per cow is Y (X) and it is sold for the gate price P. Constant cost per cow is K dollars per year. Marketing is constrained to an annual quota of Q kg milk. Productivity index is A and profits are π,

(1)

$$\begin{aligned} &\pi = PAY(X)M - CXM - KM \\ &s.t. \\ &AY(X)M \le Q \end{aligned}$$

Maximizing with respect to X and M, first order conditions yield

(2)

$$\frac{PAY(X) - cX - K}{AY(X)} = P - \frac{c}{A}\frac{\partial X}{\partial Y}$$

And by the envelope theorem,

(3)

$$\frac{\partial \pi^*}{\partial A}\frac{1}{Y(X)M} = \frac{c}{A}\frac{\partial X}{\partial Y}$$

The meaning of (3) is that, under quota, the change in profits from increased productivity is equal to the feed needed to produce the gain in milk, if it were produced. Interpretation: Under quota, productivity is not translated into additional amounts of marketed milk, rather into a reduction in the number of cows. But at the optimum (where the envelope theorem applies) the marginal cost of milk is the same whether milk is added by increased feed or by an increase in the number of cows (taking the number of cows as continuous, of course).

Dr Ehud Gelb *Former Chief Information officer of the Ministry of Agriculture and Rural Development in Israel responsible for Integration of ICT, research, information systems and applications into agricultural production, rural services, rural development and education; Information Systems and Information Technology policy coordinator; International cooperation and coordination - ICT systems development and implementation. Currently consultant on ICT in agriculture and rural development. Lecturer at the Hebrew University and Weitz Center for Development Studies, member of various scientific committees and studies in Israel and abroad.*

Prof. Yoav Kislev *is Professor (emeritus) of agricultural economics, The Hebrew University of Jerusalem, Rehovot Campus. He studied in Israel and the United States and worked in the Hebrew University, Yale University, the University of Minnesota, the World Bank and Dartmouth College. His research was on the economics of agricultural research, farm technology, development, and the water sector.*

Dr Hillary Voet *is a senior lecturer in statistics at the Faculty of Agricultural, Food and Environmental Sciences of the Hebrew University of Jerusalem. In addition to statistical assistance to researchers and students at the Faculty, she has 20 years experience in preparing sampling designs and consulting on data analysis for various agricultural institutes in Israel.*