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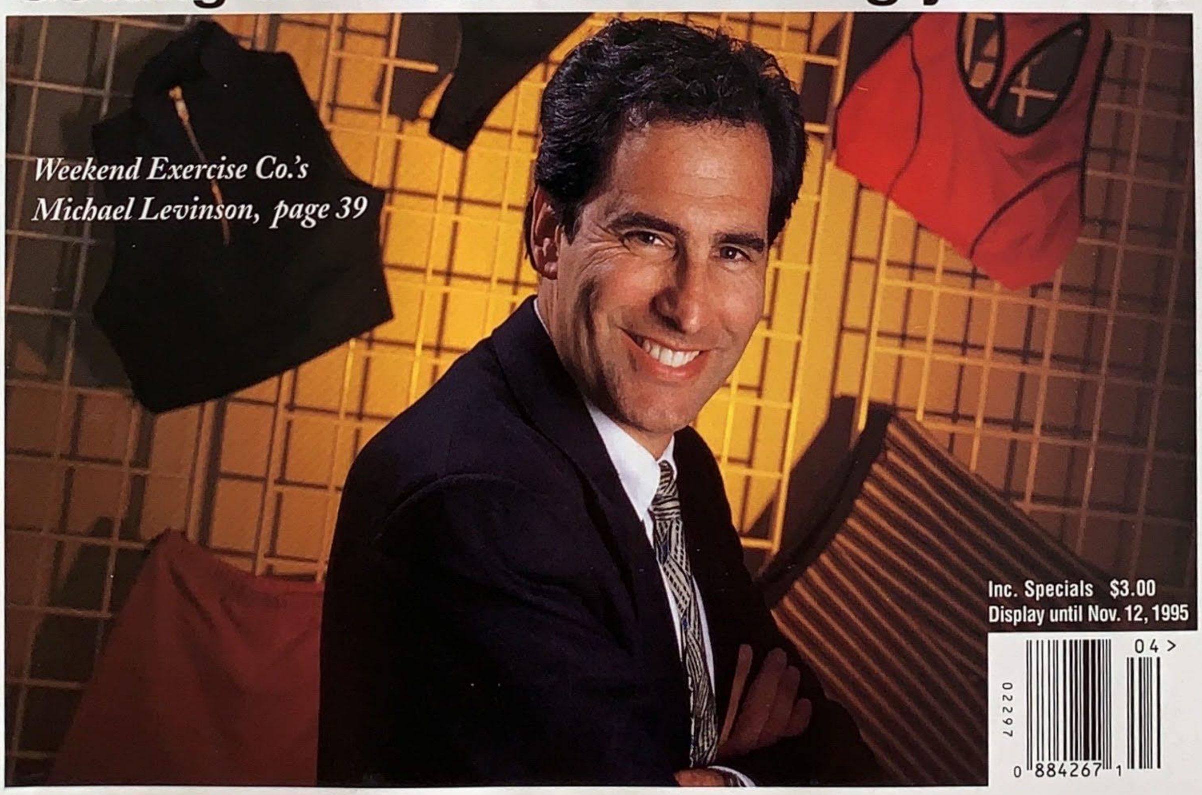

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Applications

High-Tech Harvest

Can computers do for the small farm what they've done for other businesses? More, actually

by Fred Hapgood

All last spring cold rain fell on Corn Belt fields, leaving them chilled and sodden. On the few days when no rain fell, thick clouds prevented the ground from drying out. Farmers cannot set seed in water-saturated soils (planting machinery compacts wet ground, making a poor incubator for baby roots), but they also cannot wait forever. Past a certain date, every day of delay costs the fall harvest a few percent of yield. For many farmers, that window was narrowing quickly. They stayed indoors, paced, called each other, told farmer stories, and recalled the glory years in the 1970s, when it seemed as if the price of corn would rise forever.

Some farmers, like Doug Harford of Grundy County in Illinois, were a bit better prepared. Harford, a blond column of a man in his middle forties, had laid drainage pipes under his fields, and those had carried off enough water to allow him to squeeze some seed into the ground. Still, he too had a few hours to sit inside, watch his fields soak, and sum up the roller-coaster ride he's been living since he took over his father's farm two decades back.

Every business has its uncertainties, Harford says, but farming is extreme. People in the cities read about the major droughts and floods, but the unpredictability is ever present. Crops are affected by the combination of biology (soil flora and fauna), geology (soil type), and meteorology, all of which fluctuate drastically over space and time. The same input will not produce the same output from one year to the next, nor do any two acres on one farm grow the same yield in the same year—let alone two acres from different farms. No two situations are ever equal. "People have a tendency to confuse experiences with experiments," Harford says. "Agriculture is mostly experiences."

That unpredictability defines farming culture, making farmers conservative, skeptical, and careful. It also makes farm management more of an art than a science. Other businesses can calculate the tradeoffs between marginal returns and incremental resource costs quantitatively, objectively. A farmer considering whether an extra hour of field inspection makes sense on a given acre must account for the effect of changes in soil type, seed variety, field and planting geometry, tillage practices, yield histories, drainage, pest populations, density of organic material, and so on, all of which can fluctuate wildly across a single field. Turning those variables into hard numbers requires massive amounts of measurement. In the absence of those data, farmers make do by weighing the questions "intuitively." When they do write down numbers, the numbers are estimates—what Harford calls WAGs, for "wild-assed guesses."

WAGs are not arbitrary: a skilled farmer can manage a host of complexities through "feel." But every farmer's feel has its limitations. Managing through feel sets a limit on the number of acres that can be managed effectively, which in turn limits the efficiencies of scale farmers can bring to bear. Harford believes that if food prices are going to remain low, sooner or later farm management will have to become more quantitative—less experience, more experiment.

Harford had been thinking about the problem of limitations for some time. He knew that in theory there was a solution: measuring the flow of harvested material every few seconds as it passes through the combine, addressing each measurement with the location of the field segment that each "unit" of material comes from, and then using those "addresses" to plot the yield measurements on a map. A farmer could then control the variables by overlaying the yield data with maps representing the various factors—for instance, comparing the difference in yield that comes from laying 10 units of fertilizer Y on soil type Z when Z is planted with seed "alpha" with laying 12 units of fertilizer on exactly the same combination of factors.

(Continued)

ARNOLD ZANN/BLACK STAR

Doug Harford of Grundy County, Ill., electronically tracks and adjusts for minor variations in yield over every square foot of his farm.

The theory behind the process, known as "yield monitoring," has been discussed in the academic literature since at least the 1950s and used as an instrument in agricultural research since the 1960s. Commercial farmers had not touched it because the labor required—stopping to weigh the units of harvested material every few feet, determining the coordinates of the area that had grown that unit, and handling the tremendous volume of data required to make the overlays—was prodigious. Agricultural research stations had the staff and students to do such scut work; businesses that had to make a profit did not.

In the late 1980s, as often happens, someone too far outside the industry to have heard what was and was not practical saw what seemed like a huge opportunity. Allen Myers was a power transmission engineer at the time, working for Sundstrand Corp., in Rockford, Ill. Though he was no farmer, he knew computers, and he saw that the digital engines were growing cheap and powerful enough to allow many of the most onerous information-handling yield-monitoring tasks to be automated. He also knew about a new idea in the location business. In 1983 Ronald Reagan (in the wake of the Korean Airlines Flight 007 disaster) had announced that a network of navigation satellites built by the Defense Department would be made available for civilian use. The satellites broadcast their orbital position and a time stamp continuously, allowing receivers moving around on the ground to use simple triangulation to find their location. The whole system was called GPS, for "global positioning system." Myers knew he could use the satellites to find his locations.

The single remaining difficulty was breaking the harvest into measurable units. For several years Myers worked evenings and weekends to find a way to automate that last function without forcing farmers to rebuild their harvesting equipment. Finally, he came up with a plate that stands in the flow of harvested material. A transducer behind the plate continuously measures the force striking the plate face and then sends the values to a processor, which corrects the values for complicating factors like the speed of the combine and the water content of the crop. Depending on the combine, the entire system might break up an acre into about 500 measurement units, or "elements," the agricultural equivalent of the pixels on a display screen or the dots in a newspaper photo. (A farm like Harford's, with 1,500 acres, would be represented by about 750,000 elements.)

In 1992 Myers began marketing his device, the Ag Leader Yield Monitor 2000, through a company he'd just formed, Ag Leader Technology, based in Ames, Iowa. The yield monitor cost $3,300. That year and the next, not many sold. "When farmers are harvesting, they go flat out," Myers explains. "They're a little reluctant to get involved with something that's unproved and looks as if it might force them to stop and read a manual." One of his few customers was Doug Harford, who used it during his 1993 and 1994 harvests.

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"The big surprise for me was the amount of variation in a single field," Harford says, opening a loose-leaf folder full of maps. (Myers says that his customers often report seeing a variation of 50% or more from one section of a field to another.) Each map is speckled with a dozen different colors. Every color represents a different level of soybean or corn production. In the case of soybeans, for instance, levels range from 30 bushels an acre to 70. He turns to a map of a rectangular 160-acre field with a notch in one end. Through the notched end, representing about 20 acres of land, shines a solid high-yielding green, while the rest of the field flickers through the shades of yellow and red that represent lower productivity levels. "In 1994 this green end grew 20 bushels an acre more than the rest of the field," he says. "That caught my eye. With soybeans at $5 a bushel, bringing the rest of the field to that level would make a $14,000 difference." He had no idea what was taking that money out of his pocket.

"In 1994 we were growing only soybeans in that field. When I checked the records from 1993, when we were growing corn, I didn't see the same variation. I knew in '92 we had planted soybeans in most of the field, but oats on that end," Harford says, pointing to the region that was glowing emerald in the 1994 data set. "So it looked as if we had a parasite that ate soybeans but not corn or oats—and that could survive one year without food but not two." He hired a soil-testing company to probe for microscopic wildlife. (When the researchers arrived, Harford used the data from his yield monitor to plan the pattern of their sampling sites.)

He found he had an infestation of a soybean-loving nematode that until then had been encountered mostly in the South but was known to be moving north. "This was the first time we'd seen it on that scale, distributed through a whole field like that," he says. Alerted by the monitor, Harford looked for and found the parasite in several other fields. Now he's considering his next step. He might use nematode-resistant seeds or try starving the parasite out by growing corn two years in a row, skipping the rotation with soybeans. Both alternatives have short-term disadvantages, but the evidence from the yield monitor is that the fight is well worth making.

On the other hand, sometimes the monitor makes problems go away. "I lease some of my acreage," Harford says. "Recently, I was driving through a field with its owner. We reached a section where the drainage was deteriorated a bit. The plants looked short and ugly, and partly because of that, we decided to upgrade the system.

"That would have meant replacing 8-inch-diameter pipe with 15-inch-diameter pipe and running the new size through fields belonging to three other people. The process would have been complicated and expensive." So before Harford went ahead, he checked the field on the monitor. "I found that we were losing only about $1,500 of yield in that region—and $1,500 wouldn't even have paid for the interest on the investment needed to do all that work." The ugliness of the plants had been deceptive. "We used to fix things like that," he says.

Harford is still thinking about some of the information he's gathered. "What ought to be our best soils actually turn out to have the lowest yields. Maybe that's because the most crop has been taken out of the best soils." If he settles on that hypothesis, he might add more fertilizer to the very soils that are supposed to need it least. (Currently, the same amount of fertilizer is added to low- and high-yielding fields.) Yet his data—which he quickly points out are very limited—don't support any direct relationship between productivity and fertilizer distribution. "That's interesting," he says, shaking his head. "That sure isn't what the fertilizer companies tell you."

Harford expects yield monitoring to play a big role in his technology management. Every year, the seed, machinery, and chemical companies pump a small river of studies through Harford's fax machine, all showing the handsome increases in productivity awaiting any farmer canny enough to buy their products. "They always seem to claim to give you about 6 bushels an acre more [corn]," he says. "Does this mean that if I bought everything, I'd grow 300 bushels an acre?" (Even 200 bushels would make an excellent year.) "I doubt it."

Harford knows that just because a product did something heroic 150 miles to the south last year doesn't mean it will do anything on his farm this year. It might never grow the six extra bushels in his particular region to begin with, and even if it does, unrelated factors might depress production by six bushels, preventing him from noticing the improvement. The only dependable way to evaluate a technology is to "amplify" the signal over time by using it on the same fields for many years running, but that necessarily retards the rate of innovation. Harford tries to stay up-to-date with new seeds—he has 12 varieties in his fields this year, the oldest all of four years old—but he suspects sometimes that his decisions are really driven by vendors. "We have our complaint of the month," he says. "The salesmen all sell to that."

A farmer armed with a yield monitor is not such an easy target. "We've always had to take other people's data, gathered from other people's fields," Harford says. "Now we have our own data, gathered from our own fields. If a seed salesman promises me six bushels and his seed doesn't deliver, I'll know in a year. And so will he. To a farmer, validation is power."

ARNOLD ZANN/BLACK STAR

TRACTOR TECH: *The roof-mounted global positioning system allows fine-tuned farming.*

Only 200 farmers used the yield monitor with the GPS package for the 1994 harvest, but Harford is sure the device will spread quickly because the effect on revenues is so great. (Myers says his sales have quadrupled this year, and John Deere, a farm-machinery and equipment manufacturer headquartered in Moline, Ill., has announced plans for a combine that will come with yield monitoring built in.) Moreover, the technology will only get more powerful, as on-the-fly testers are developed to measure different soil properties (nitrogen, pH, phosphates) continuously and as equipment appears that can handle each field unit separately—for example, matching the right seed to the right soil or applying quantities of fertilizer or chemicals that are specific to each unit. Perhaps in the near future, farmers will be yielding two "crops": one measured in bushels—and the data itself, measured in bits.

The implications for agriculture are profound. Leading-edge farmers will likely become far more experimental because they will be able to prove theories and put them into practice very quickly. Harford expects farm size to grow significantly—and yield monitoring to make it possible to handle far more variables than in the past. Farms already have been growing, from a national average of about 350 acres in 1967 to 500 acres in 1994, but Harford says he wouldn't be surprised to see consolidation proceed much faster over the next 20 years.

On a deeper level, Harford suspects yield monitoring might help change the basic paradigm of farming to one in which farmers adapt to the soil instead of forcing the soil to adapt to them. He makes his point by pulling out a map: "We have these drainage pipes running under the fields. Sometimes the soil settles down between them, making parallel rills. They're annoying to run over, so last year I trimmed them down. And yield went down. Right there."

That was not a big surprise to Harford; he likes to point out that corn did not evolve in a world in which the ground was being plowed up every year. He thinks soil is more usefully seen as a biological tissue, organized around common systems and networks of exchange and circulation, than an inorganic commodity that can be torn up and ripped apart. But the issue has caused some debate among farmers. Now Harford has the numbers.

Every technology has its dark side, and yield monitoring also raises the possibility that crop farming might end up where poultry farming is now: so rationalized and controlled that it can be done by 9-to-5 corporate employees or even by robots. That won't necessarily happen, but it's possible that Harford has picked up a tool that eventually will leave no room in agriculture for a person of his skills and intelligence. It's a gamble; it's an unknown; but, of course, if Harford were afraid of unknowns, he would never have become a farmer in the first place. ❍

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