UNIT III

Agricultural systems - managerial overview, Reliability of agricultural systems, Simulation of crop growth and field operations, Optimizing the use of resources, Linear programming, Project scheduling, Artificial intelligence and decision support systems.

AGRICULTURAL SYSTEMS MANAGEMENT AGRICULTURAL

SYSTEMS DEFINED

- An agricultural system is a specified group of components, operational functions, and processes that are integrated to accomplish a well-defined purpose.
- Agricultural systems managers (ASMs) usually plan, evaluate, and adjust a system or some group of components of a system. In a complex agricultural system one can easily identify or envision systems within systems.
- We might call those systems within systems subsystems, but the main concern is that the system performs to the highest level we can achieve within the parameters or resources at hand.
- The ASM must learn quickly to manage and evaluate subsystems concurrently.

CHARACTERISTICS OF AGRICULTURAL SYSTEMS

- Each agricultural system has some well- defined purpose. The purpose might be stated simply, or more often it might be stated as a group of objectives.
- And those objectives might include some very definite specifications or measures of performance.
- As an example, let's consider an agricultural system that produces potato chips. The overall purpose might be to produce six 1 2= -ounce bags of chips for the consumer market.
- However, the well-defined purpose for the line technical mangers of the processing plant might be production objectives of 1500 bags per hour, less than 0.05% of bags over 0.675 ounces, with less than 8.00% waste, less than 1% under 0.6355 ounces, with less than 0.5 hours line downtime per shift, less than 1 recorded human accident per 6 months, at a cost of less than $0.233 per bag, and meeting the 2002 EPA guidelines regarding odor control in the community.
- In real life this specification list could be much longer, involving hours of planning and discussion with managers, engineers, accountants, labour unions, and lawyers.

We could easily identify the same level of complexity in a production farming operation. The overall purpose might simply be to grow hogs for meat processing. The well-defined purpose might be to produce 1000 barrows, with weight range limited to 205–215 lb, loin eyes of not less than 4.14 sq in or

more than 5.01 sq in, average rates of gain of not less than 1.98 lb/day, at a cost of less than $0.21 per pound, utilizing non GMO feeds, and meeting all local and federal EPA requirements. And, once again, the real pork producers reading this chapter know that an actual specification list for this agricultural system would be much longer. This discussion of the ‘‘well-defined purpose’’ portion of the definition is well served by the two examples. Looking back at our potato chip processing plant example, we know that to fulfil the well-defined purpose (specifications), numerous operational functions and processes need to be performed. The operational functions and processes are key parts of our definition. Some of those operational functions and processes involving our complete definition of the potato chip agricultural system might be:

- Purchasing of potatoes
- Transportation
- Unloading at the plant
- Storage
- Grading and inspection
- Sorting
- Chemical wash
- Storage
- Waste disposal
- Purchasing of frying oils
- Transportation of oils
- Storage of oils
- Least-cost formulation of ingredients
- Cutting processes
- Line movement of product
- Frying
- Salting
- Packaging/weighing
- Boxing
- Quality control
- Pricing
- Loading
- Distribution and storage
- Sales
- Transport

In this agricultural system each operation or process might require humans, machine components, or a chemical or biological process. And each process will have management-defined parameters for successful operation. We could construct elaborate diagrams or computer programs to inspect or evaluate each component or operational activity. But our mission is to manage agricultural systems to achieve goals. To do that, we must fully understand how each component of a system works and the interacting effect its application might have on other components and the outcome of the system. To predict those impacts, we can rely on mathematical models and tools to forecast outcomes of decision alternatives.

EXPECTED OUTCOMES OR ‘‘DELIVERABLES’’ OF AGRICULTURAL SYSTEMS

There is a real need for the system to deliver well-defined products. Today's consumer-oriented market demands truth and performance. A system often must meet standards either the consumer wants or governments might demand. Let us consider the challenge a small organic fertilizer bagging plant might have. The manager must meet the desires of the company for profit, of the public for performance, and of the government for truth in packaging. The manager and the company must design a product that meets the specification that satisfy company upper management for profit, establish product features that entice a certain market share of buyers and meets state and federal analysis on the package label. Each fertilizer product becomes very well defined, and the agricultural processing system must meet the goals. Many people from many arenas give critical input.

It is expected that the products the production line delivers are profitable. Agriculture is a business Every business must in the end meet a profit goal. In this small organic fertilizer bagging business we must set production volume targets, estimate fixed and variable costs, and establish costs per bag, pricing, and target profits. If this was all there was to management of this line, it would be easy. However, agricultural systems have to satisfy many other conditions. Profitability is not enough. The product must be safe for use. The manufacturer must also guarantee the safety of the production workers and perhaps meet union work conditions. If the product were edible or a drug it would have to be safe for human consumption Certain aspects of quality control would have to be met and verified.

Our bagging plant would probably produce ‘‘secondary’’ compounds or wastes. They must be managed as well. Those processes and costs become part of the total agricultural system too. The plant is responsible in American society to maintain or enhance the environment. Or at the very least, the product must be produced at environmental costs that society (and the law) deems acceptable. It is not unusual to expect that the bagging plant system also contribute to the general community economic development and well-being.

THE PRIMARY GOALS OF AGRICULTURAL SYSTEMS MANAGERS

An all-too-common mistake of technical management is a failure to identify performance criteria against which the system must be evaluated. These criteria and their measures need to be well established before we ‘‘flip the switch’’ and a system begins to operate.

The goals, criteria for success, and performance measurement assessment should be part and parcel of every planning process and evaluation process. These performance criteria should be established up front and agreed upon by all management.

It is not unusual to see these measures as part of monthly, quarterly, and annual reports. Some primary goals agricultural systems managers must attain are:

1. Optimization of economic costs, profits, and benefits
2. Production of defined levels of product quality and
3. quantity
4. Meeting timelines and schedules
5. Delivery of value-added products and product attributes
6. Attaining acceptable process reliability
7. Maximization of e efficiencies
8. Realization of environmental and regulatory guidelines
9. Optimization of human factors—safety, job satisfaction,
10. performance factors, and perhaps labor union issues

CRITERIA OF EVALUATION

Obviously, production costs per bag of chips would be a key criterion to evaluate, or maybe the total volume over a week, or total production in bags over the year.

So, costs, volumes, and profits are key criteria. Efficiency of the processes can be measured, equipment adjustments made, or replacement of processes effected.

Some of the processes included truck unloading, storage, belt movement, cutting, frying, salting, sorting, weighing, bagging, and boxing. Product quality must also be assessed.

Yes, we all like a beautiful, unbroken chip! The size, colour, weight, etc can all be assessed. Storage life and condition of the package itself can be evaluated and goals set No one likes a wrinkled bag or a misprinted label.

And who wants a six-ounce bag of chips labelled as seven ounces? If we forget that the whole system must have a very high-performance reliability, we cannot achieve any other goals.

To achieve this, we must meet timelines and schedules and attain serviceability and machine replacement goals. In a production plant we are always scrutinizing resource utilization, waste reduction, risk minimization, performance, stability, environmental impacts, FDA guidelines, food safety guidelines, and state and federal regulations.

Today, food processes must meet purity and process standards. Then there is the human element.

Are the plant meeting union agreements? Some additional criteria for evaluation would be meeting goals in plant safety, personnel satisfaction, health, comfort, and plant security.

The ASM must approach the system management from a team perspective. Many have input. Many must be informed and empowered. It becomes quite clear that a good technical manager manages far more than money.

Managing means managing all the resources. The good technical manager must also consider machine replacement, new products, new technologies, and training of personnel.

FACTORS AFFECTING THE AGRICULTURAL SYSTEM AND THE ASM'S DECISION MAKING

1. **Changes in Weather, Seasonality, or Biological Intrusions**

Perhaps the most significant and unique factor in agricultural systems management is dealing with the weather or seasonality of commodity production.

In our organic bagging plant example, an unknown or unplanned warm weather span could greatly spur biological activity of stored wood chips or manure.

Rising temperatures or microbe levels in the potato storage sheds would cause the potato chip manger to have to adapt to these conditions. Many processed products of agricultural systems are live biological entities requiring heating, cooling, pasteurization, sterilization, fermentation, or even radiation.

Seasonal changes or unusual weather patterns can greatly change schedules in Beld planting of corn or harvesting of soybeans. A meat processor knows that biological processes occur in known time frames. He or she must acknowledge and respond to unusual temperatures.

Processing changes must occur, or product quality is lost—or the product itself could be lost entirely.

A Florida citrus grower must change processes if an unusual cold snap jeopardizes the life of a young fruit tree Or if a disease such as aflatoxin enters a corn Beld nearing harvest, an immediate response by the ASM is required.

In production agriculture one must always be prepared to alter decisions when plant or animal diseases enter or threaten. The threat of SDS (sudden death syndrome) to a soybean crop would require changes in variety selection, planting dates, and harvest dates.

Likewise, a dry year would certainly spur the ASM of a grape vineyard to engage irrigation scheduling. The same dry year would spur the ASM of a winery to change the formulation of his winemaking process, since the soluble solids count of the grape juice would increase in a dry year.

In a wet year, the count may drop and the ASM might add sugar to fermentation processes.

2. **CHANGES IN TECHNOLOGY**

All so often dramatic changes in technology or innovations impact the agricultural system so much that the ASM is required to completely change the components, functions, or processes of the systems. In other words, we completely change the way we do things.

One dramatic example of this is the impact of biotechnology techniques and nanotechnology equipment on the development of plant seeds. The new technology completely changed how we exchange genetic information to form new varieties.

Processes were changed, new skills were required, and old seed technology was rendered noncompetitive. While this new technology changed forever how we promulgate plants, it also changed how we grow them in the Beld Genetically modified plants are now collegial in being resistant to certain herbicides.

Thus, we also have modified the cultivation and pesticide application in the production Beld systems of agriculture. Changing a technological process is not the only impact of changing technology. The development of a new product can
greatly change an agricultural system.

The invention of the large round hay baler is a good example. The introduction of the machine completely revolutionized haymaking in the Midwest, where labour costs are high. The old system of baling hay in small rectangular bales was rendered economically noncompetitive, except in specialty markets. Likewise, another biotechnological breakthrough is allowing us to grow pharmaceutical proteins and compounds in corn.

Several billion dollars a year is now generated by growing this new ‘‘Pharma’’ corn product, but the system of growing and handling requires new and unusual techniques to ensure biological security of plant growing regions ‘‘Pharming’’ requires many changes in the agricultural system.

Sometimes the breakthroughs can come from other industries or other countries. Agricultural industries and systems were greatly affected when other manufacturing industries began to adopt and develop different sweeteners.

Corn growers benefited from high-fructose sweetener, while sugar cane growers were forced to change production methods to remain competitive.

Better irrigation technology in Israel and Brazil forced growers of citrus in Florida, Arizona, and Texas to completely change irrigation technology to remain competitive. Some examples of technology changes of great impact
would be:

- Analog/digital interfacing with microcomputers
- Global positioning systems (GPS)
- Introduction of microcomputers for data handling and
- controls
- Spreadsheet software
- New plastic extrusion methods
- Ethanol processing from corn
- Rotary threshing mechanisms in combines
- Ergonomic engineering of tractor cabs
- Soil conservation practices
- The cotton gin
- Evaporative cooling for greenhouses
- Hydra cooling of fruits and vegetables
- Irradiation of meats, fruits, and vegetables

The list is very long and continues to grow daily. One of new technologies having the most impact is the use of the Internet for marketing and purchasing—commonly called e-commerce. E-commerce now allows an ASM to purchase and market worldwide. Top ASMs will need information systems that allow them to be educated rapidly regarding new developments. The Internet itself is a technological addition that has had perhaps the most dramatic effect on 21st century agriculture.

3. LEGAL/POLITICAL FACTORS

New laws and regulations can have great impacts on decisions regarding Beld production, manufacturing and processing, and technical marketing areas of agricultural systems. Even without new laws, new rulings by regulatory agencies can have consequences.

Changes in the tax structure can have significant impacts on management. Throughout the 1970s and early 1980s, farmers enjoyed federal tax exclusions from an investment credit deduction. Farmers could derive great benefits that encouraged buying capital equipment such as tractors, combines, and portable buildings. Federal tax reform removed these advantages, and equipment replacement planning strategies changed greatly. Because many did not know their income status until late in the year, there was a lot of lastminute December purchasing. This last-minute buying ceased. This change affected not only farmer purchasing but the way money was spent. Manufacturing schedules, technical sales programs and activities, and managerial decisions were changed. Even tax accountants had to change their schedules of activity.

Some of the most significant laws now affect the livestock production industry. Some small rural cities now have ''influence'' up to three miles from their city limits regarding odor control. Many local agencies in counties now control animal unit limits. Changes in fees for grazing on public lands in the West are another example where ranchers are forced to manage differently under different rate structures.

Laws affecting migrant labor, labor camp conditions, and wage rates greatly affect the fruit and vegetable industries. The trade-off between labor and mechanization greatly changes.

Likewise, Occupational Safety and Health Administration (OSHA) regulations and labor laws impact management decisions in processing plants.

On the technical marketing scene, the North American Free Trade Agreement (NAFTA) has changed the playing Beld considerably. Some industries have greatly benefited, while others have suffered. Changes in EPA guidelines and standards now have great managerial impact regarding the use of fertilizers and pesticides.

Nonpoint and point sources of watershed runoff are now more controlled. The ASM must keep abreast of key local, national, and international issues. Some key governmental agencies are:

1. Bureau of Land Management
2. EPA
3. State Departments of Agriculture
4. Water management districts
5. Farm Services
6. US Forest Service
7. Zoning commissions
8. Department of the Interior
9. Bureau of Indian AAairs
10. Agricultural Plant Health Inspection Service (APHIS)
11. Homeland Security

4. The Economy

Since the events of Sept. 11, 2001, we have learned how catastrophes can send an economy reeling for many months. Numerous factors in the economy can affect agricultural systems decisions. Managers in the manufacturing and processing areas certainly must be in tune with changes in the economy. Some key factors of change include oscillating inventory levels for supplies, available disposable income, new housing starts, changes in gross domestic product (GDP), expansion/failures of businesses, price levels, and changes in exports or imports.

Today, agriculture faces many changes in marketing channels for livestock, increasing mergers of seed and chemical companies, and consolidation of equipment suppliers. Yet new opportunities abound in the emergence of alternative fuel processors and new crop initiatives.

5. **Changing Societal Trends**

Society's attitudes are constantly changing and evolving. A number of attitude changes have greatly impacted agricultural systems. Perhaps the most important has been in the attitude toward the environment.

A growing spirit of conservation and preservation of wildlife and habitat has spurred numerous changes in agricultural systems management. In the early 1990s, support for the Pacific Northwest's spotted owl changed many lives. The giant logging industry, through public opinion, was forced to change its cultural and harvesting practices.

The industry continues, but not until after many systems changes were implemented. Managers must look ahead and be considerate of society's attitudes or perhaps pay a larger price—being forced out of existence. Society now focuses more keenly on the effects of production practices, including biotechnology, waste disposal, water quality, chemical waste, and odor generation.

Other attitude changes during the past decade have included:

1. Change in attitude toward the use of electronics and
2. computing technologies
3. Change in attitude toward the use of credit
4. Change in attitude toward increased leisure time
5. Change in attitude toward the use of foreign products
6. Change in attitude toward health and Fitness
7. Change in attitude toward cultural diversity
8. Change in attitude toward higher education
9. Change in attitude toward human and animal health
10. Increased desire for food safety
11. Increased desire for protection from terrorism

Unfortunately, many of these attitude changes have brought about increased regulation of a system manager's activities. In order for the technical manager to be successful in the long run, he or she must not limit his or her continuing education activities to technical updates alone. One must develop a good ‘‘crystal ball’’ by following and participating in many cross educational activities, including local, state, federal, and international politics. Some of these changes in attitudes have encouraged whole ‘‘new’’ industries. The desire for increased leisure and the desire to enjoy the ‘‘good life’’ have generated the new area of agritourism. Industries such as hunting preserves, Bushing resorts, bed-and-breakfast inns, grape vineyards and wineries, farmers markets, maple syrup festivals, and equine events now abound.

6. **The Competition**

Someone else is always playing the same game. Decisions by the competition sometimes affect the strategy of another ASM's planning and ultimately the outcome of those decisions. Often, we may be affecting one and the same system. Awareness of what others are doing to that system is important.

Competitors' decisions or actions can affect the economic well-being of other firms or entities. The entry of new competitors does not always mean disaster for existing firms, but it can—especially if management does nothing to secure its position. A new competitor may force expansion in order to get lower cost per unit benefits. A new competitor may force the changing of hours of operation, additional investments, review of the product lines, expansion, or closures. Competition may come from foreign markets, such as lower-cost produced pork from Argentina or Brazil.

The competition's addition of a new or improved product often changes the business or management of a system. A seed company may add a new biotechnology-developed seed. A steel building system might have improved life. The introduction of retort packaging or irradiated food could change marketing, processing, or packaging systems.
Competition might introduce new selling or marketing strategies. Promotion of Angus beef might encourage growers to produce more Angus beef and less of other breeds of cattle. New marketing strategies might change how one would package the product. Or sometimes the new package itself creates the need for changes in processing.
Competition might obtain new customers, which gives them either economies of scale or a new niche market. In the late 1980s the Florida corporation Naples Tomato Growers landed the account to supply all tomatoes used by McDonald's Corporation. The security of a contracted major account afforded them a number of new managerial options.

New markets are always being sought. Competitors who might find them first win the opportunity, at least briefly, to attain economies of scale. The adoption of NAFTA opened many doors and opportunities for many agricultural industries. Clearly, irrigation sales, food equipment sales, and aquaculture equipment sales to Mexico were some of those new markets open for a short time. Perhaps one of the most exciting new markets exists in China. Without a doubt China can be America's largest new market for corn, soybeans, and other commodities.

The adoption of new, more efficient processes or management strategies can change cost structure rapidly as well. In the 1970s Japan adopted new steel-making technologies that forever changed the world industrial markets for steel. And in the decade of 2000, the American technological expansion of Internet and software technologies is greatly changing the face of all systems management.

Changes in Clients' Needs

The customer is always changing, and so are customers' needs. The ASM must develop mechanisms that allow timely interaction as clients develop strategic plans. Regrettably, many ASMs have become so engrossed in their own firm's plan that they simply overlook the changing needs of the customer. And before long another firm is taking care of those changing needs.

Consumer needs change constantly. A good case study is that of the consumer acceptance of genetically modified products (GMs), or products from genetically modified organisms (GMOs). European consumers and those in the United Kingdom are keenly aware of food safety issues. Their perception (right or wrong) is that GMO- developed food products may not be safe. Hence, they do not want GMO products mixed with non-GMO products. ASMs in the United States may have to change many operations, functions, and equipment pieces in order to have a food system that can deliver a 100% non-GMO product.
And Americans have grown, literally. The average American is taller, larger, and overweight. Clothes makers have to make those shirts bigger!

Changes in the ASM's or Firm's Purpose

The ASM and his or her firm is an entity that also changes, grows, adds and drops obligations, and responds to new opportunities and challenges. The agricultural system must change in personnel, functions, purpose, activities, and goals. A self-assessment process is a vital part of ongoing management of the total system.

In summary, the performance of the system is greatly influenced by the ASM's decisions. Success is determined by how well the ASM adjusts for changes in:

- Weather

- Seasonality
- Biological intrusions
- Technology
- Legal and political regulation
- The economy
- Societal trends

- Competition
- Customer or client needs

TOOLS FOR PLANNING, MANAGING, AND EVALUATING

The bottom line as to whether management is good or not is whether the system is meeting performance specifications or improving. Validating that the system is on the upswing can be very difficult. Verification requires measuring and analysis techniques. To do this, a process requires a six-step loop:

1. Sensing
2. Information storage
3. Information processing and analysis
4. Evaluation
5. Decision
6. Action or change
7. And back to sensing, etc

A manager might utilize this testing process to improve the system on a weekly basis or even a daily basis. Imagine the potato chip processing line manager we discussed earlier. The chip process might be sampled and adjusted every few minutes or even seconds. Improvement requires planning and management tools. Mathematical models are often used for planning and evaluation. Any agricultural system can be analyzed utilizing mathematical tools if it can be described logically. In most cases, approximation, record- keeping, sensing devices, electronic monitors, satellite imaging, or statistical sampling techniques will yield enough accurate data for management to begin planning and evaluation.

Quite a number of today's best technical management tools are mathematical models disguised as computer software packages. Many of those packages will be explored in the upcoming chapters of this book. Good examples are spreadsheets, linear programs, scheduling routines, and simulations.

One can begin to see that the skills required to be a successful ASM have a wide range, based on the varied activities this technical manager must oversee. Managerial skills are needed in:

- Accounting and finance

- Organizational planning
- Scheduling
- Systems reliability planning
- Personnel
- Human factors and human safety
- Environmental planning
- Pricing and costing
- Data information and management
- Transportation analysis
- Biological, chemical, and physical management
- Decision systems
- Systems integration
- Promotion and sales planning
- Legal and regulatory planning

Ideally, a strong ASM will have an academic preparation that is strong in engineering technology, the sciences, and business. The use of statistics and computer tools is paramount. Fortunately, there are many good software packages today to assist the ASM. And the Internet can be an excellent source of current information. The upcoming chapters will tie some of today's common agricultural systems challenges to a problem- solving framework utilizing some of the more popular mathematical models and contemporary software packages available today.

RELIABILITY OF AGRICULTURAL SYSTEMS

The goal of every agricultural systems manager (ASM) is to develop a total system that functions without fail. We know that this is an unobtainable goal, yet we strive to approach this by setting a goal of some successful percentage, such as 97% of the time the system operates as we need it. In order to obtain a high reliability for a system we must set a reasonable goal and plan for how to get there. The planning involves analysis of each component and function of the system. Then we consider what devices are replaced, which require backup, and how much we can afford to spend on our way to attaining the system reliability goal.

Measuring performance of a system can be done in several ways, all depending on which of the criteria we wish to evaluate. The technical manager spends a high proportion of time evaluating the performance of the system. Every agricultural system can be viewed as a group of processes and components (including humans) that must perform satisfactorily and in a timely fashion to achieve the output we have specified. Within our context we shall consider reliability to generally mean the probability that our system performs successfully. And we as managers will predetermine what "success" is.

We will now explore some of the management implications of our working definition of reliability within the context of agricultural systems. In production management reliability is most often viewed as the probability that the system will perform satisfactorily when called upon under specified conditions. Thus, reliability of a system, a subsystem, a function, or a component is measured in terms of probabilities. Quantitatively, a component or system is expressed as 0.9999 or 0.94 or some positive value less than 1.00. It should be noted that not all the system components necessarily have to perform at the same time, but each component must operate at the proper time for a sufficient period of time to ensure that the system accomplishes its purpose. Operation of the jet propulsion engine on a space shuttle launch is a good example. The engine must perform for only a few critical minutes in the proper way to be deemed successful.

A critical part of the definition of reliability is the "specified conditions" under which a unit or component is to function. Systems that would perform under all extremes of heat, dust, humidity, poor field or manufacturing conditions, vibration, and mismanagement and all possible conditions would be ideal—ideal but not very realistic. Systems must be evaluated within the limits of their intended use. These conditions should be explicitly stated or recognized before evaluating the performance reliability of a system. For example, it would not be a fair evaluation to state that the reliability was poor if a citrus harvest system failed because the hydraulic lift truck for moving pallets was stolen, or if a computer designed to operate in an air-conditioned working environment failed because it was exposed to 125°F temperatures in an incubation chamber. It is the job of the technical or agricultural systems manager to assist in planning and in setting needed, reasonable expectations.

Some critical processes may require component performances of extremely high reliability (launching astronauts, embryo incubation, refrigeration, evaporators, etc.). The words perform satisfactorily also carry great significance in the definition and in understanding the performance reliability concept. Tolerances must be specified so as to establish what acceptable reliability means. From the very beginning of the existence of a system degradation begins. As each component within the system ages, wears, or depletes with use, the output or system performance begins to vary. For a substantial period, the variance may be so minimal that it is not worthy of notice. Eventually the system may continue to function, but not at an acceptable level. A corn harvesting system consisting of a combine, tractor, wagons, augers, bucket elevators, grain drier, and storage bins is a good example. As the combine ages, field losses of grain increase. As the augers and bucket elevators wear, grain kernel damage increases and system flow rates decline. Drying rates may increase and fuel costs rise. There eventually comes a time when the unacceptable level is reached, and the system is deemed no longer reliable. One day the value may be 0.91 and the next day it can be deemed inoperable (zero). The manager can elect to replace components, change the system, get backup units, or even hire another system to perform the task.

Setting the acceptable levels of performance of various components is not always easy.

First, one must recognize what criteria are typical. The following criteria often need acceptability levels established in field production agriculture:

- Speed of operation
- Crop loss acceptability
- Quality and condition of crop
- Timeliness of completion date or times
- Cost–profitability trade-offs
- Field efficiency
- Capacity of each system needed

To dwell on this topic of acceptability for just a moment, we might consider a farmer evaluating the levels of acceptability regarding capacity of his soybean harvest system. Due to the limited days of good weather in his Midwest fall season, he may know that his harvest system must maintain the overall daily capacity of 55 acres per day. If harvest capacity is less, he does not get all of the crops in before the snow arrives and ends the season. Low reliability or high downtime, as he may phrase it, would not be acceptable. Likewise, a corn producer must view the quality of the harvested crop. It would do no good to continue running a combine if the threshing unit had become so worn that the machine produced a crop with

20% of kernels cracked. The crop would be evaluated poorly when graded at the grain terminal and deemed a very low market grade (sample grade would yield a very low price)!
In biological processing, packaging, or food processing, added factors such as the following could be determinants:

- Percent loss
- Yield
- Critical time durations met
- Cost per unit
- Food quality
- Food safety
- Contamination
- Cost of rework

Let's suppose a pecan processor is making bagged, crushed nuts for a candy manufacturer. The pecan processor delivers several truckloads of nuts. It is found that the nuts contain many pieces of shell. The candy manufacturer rejects the product (they do not want lawsuits from customers who break their teeth). If it is found that the screening devices are no longer capable of use because they are too worn, then the reliability of the processing line becomes zero.

HUMAN INTERACTIONS

Most agricultural systems consist of mechanical equipment and humans. In some cases biological, chemical, or physical processes are components as well. Humans are often required for planning, initiation, maintenance, operation, vigilance, ending operations, or any variety of tasks. They may provide the "backup" to any number of potentially failed components.

If one considers only equipment or process factors in systems planning, then one is assuming operator performance to have the probability of $r = 1.00$. Obviously, the reliability of humans is not perfect, or 1.00. Leaving out the valuation of human elements would give grossly inflated systems reliabilities, as often happens. However, the proper management of human interaction can lead toward exceptionally high systems reliability, as we will see later in this chapter.

Humans are much more complex than any machine or process used in agricultural systems today. The challenge of duplicating higher human functions such as perception, recognition, and decision making has just begun, through artificial intelligence algorithms and electronic circuitry. The field of robotics is still expensive and in its infancy.

Human limitations are numerous. They are less stable than machines and are influenced by and more responsive to the work environment. Human performance is affected by physiological conditions, fatigue, noise, incentives, rewards, previous learning, and conditioning (good and bad). However, thanks to the study of human factors, or ergonomics, it is possible to treat human operators mathematically, as one does for other components and processes as we estimate reliability of systems. In terms of inputs and outputs, a common descriptive language exists from empirically derived research. This permits a mathematical treatment that can be applied to man, machine, or processes. We will return to this topic.

ESTIMATING THE SYSTEMS RELIABILITY VALUES

There are many questions for which estimation of reliability can assist in providing technical management answers. Always remember: The system must work when you need it. If it doesn't, all other aspects of a system are irrelevant. Here are just a few of the decisions that quantification can help answer:

- What percent of the time does this system really work?
- Which machine should be replaced to gain reliability?
- Should a new machine (or person) be purchased, or can a used machine be utilized?
- If other machines are available for "backup," how will this affect performance?
- How many "backup" units are needed?
- Which is more profitable renting, buying, or leasing?
- Will the system work if a particular unit fails?
- How does the human operator or manager in the system affect the probability of success? Do we need more management or less?
- How much will I gain in efficiency and capacity by increasing reliability or decreasing it and saving costs?
- What level of reliability is economically acceptable?

Production managers, salespersons, service personnel, and design engineers need to fully understand that system reliability is inherently the absolute bottom line in selecting equipment, people, and resources. Granted, selections are often made for other reasons (economic, safety, etc.), but reliability must always be at an acceptable level.

Estimating System Reliabilities

Components in Series

Many agricultural systems are arranged in series. The successful operation of a series system depends upon the successful performance of each component in the system: man; machine; or process. Two conditions often exist:

(1) Failure of any given unit results in a complete system failure, and

(2) the component failures are independent of each other.

Gordon showed that in series systems the probability that a system operates acceptably is the product of the reliabilities of the individual units or components.

If, for example, there are three components in a system, each with a reliability of 0.90, the reliability of the system would be a product of the three, or 0.729. Lusser presented the original formula for sequential events as:

$$R_{\text{system}} = R_1 {}^* R_2 {}^* R_3 {}^* \cdots {}^* R_n \tag{2-1}$$

The inherent weakness of most agricultural systems is the sequential nature, leading to overall low system performance reliability [4]. Think of a simple wheat harvesting system consisting of a tractor (0.90) to pull a wagon (0.90) that the combine (0.85) unloads into a storage tank (Fig. 2-1). The system reliability is only 0.6885. One unit fails and the whole system stops. As more units are added to an agricultural system, each unit must be very close to unity (1.00) if the system is to remain acceptable. There are three possibilities for improving a system:

1. Replace components of lowest reliability with higher-valued units.
2. Use only components of high reliability (new equipment).
3. Use redundant components (provide dedicated "backup" units).

Figure 2-1 Three units in series: $R_{\text{system}} = 0.90 * 0.90 * 0.85 = 0.6885$.

With parallel units, there are two or more that are performing the same function or are available to perform the same function at any particular time. This is referred to as either "backup" or redundancy. NASA missile research showed that parallel system reliability of like units can be estimated by combining the probabilities of unit success (reliabilities) of the individual units using the following formula [2]:

$$R_{\text{system}} = [1 - (1 - r)^m]^n \tag{2-2}$$

where:

- Rsystem is the reliability of the system.
- r is the reliability of a single unit.
- m is the number of components in parallel for each function.
- n is the number of functions the unit must perform.

Suppose one were baling hay and a tractor is needed to pull and power the baler. The farmer needs only a single functioning tractor at one time to pull the hay baler. However, if he had two identical tractors, both available 100% of the time if needed and, say, with unit reliabilities of 0.90, the joint probability of having a tractor available to pull the baler would be (Fig. 2-2):

$$\begin{aligned} R_{\text{tractor fuction}} &= [1 - (1 - 0.9)^2]^1 \\ &= 0.99 \end{aligned}$$

Thus, even with relatively low component reliabilities such as 0.70, a system with four units in parallel could achieve a system reliability of 0.992. In some systems the components could be very different types, such as a human backing up a machine unit, or vice versa.
Achieving redundancy, or "backup," in a system can be accomplished in several ways. Some common management alternatives are:

- Purchasing another machine
- Borrowing a "backup" machine when needed
- Using a unit from another operation
- Leasing another unit
- Renting another unit
- Assured availability warranty from manufacturer

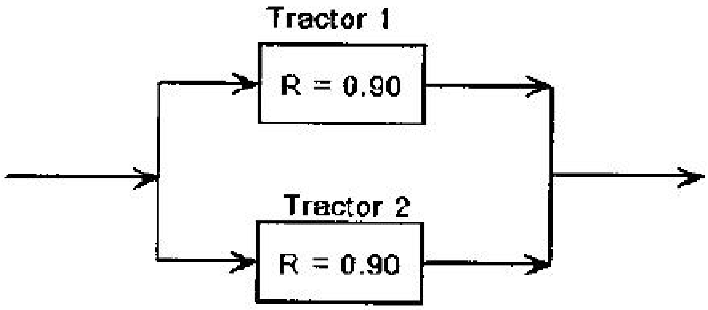


Figure 2-2 Parallel identical units: $R_{sys} = [1 - (0.1)^2]^1 = 0.99$.

Equation (2-2) is very useful because it expresses the real world of agricultural systems fairly well. The equation, however, applies only where the components in parallel for each of the n functions is exactly the same and unit reliability of each component is the same. Where these conditions do not apply, the derivation becomes more complex. And in reality it is rare to find two components or processes that are identical. For example,

a new tractor may be in use with a reliability value of 0.95; but if the new tractor were to fail, the manager might bring in the old tractor from the shed (0.78) to back the newer unit up. This situation is very typical in field production agriculture and processing. Complexity occurs in deriving a set of equations, since the selection of the first unit is a parameter open to management. An iterative technique is essential.

Heterogeneous Units

Redundant units in parallel possessing different reliability values can be termed heterogeneous backup units. An iterative technique would work as follows: For the components in parallel, select the first. If the system only had that one, that subsystem reliability, Rs, would be equal to that of the component, R1. The reliability of the subsystem that included both components 1 and 2 (call it Rs(1,2)) would be the probability that the first unit functions (R1) plus the probability that the first unit fails (1 - R1) and the backup unit functions (R2). These last two reliabilities are multiplied to get the reliability of the backup system's functioning. Therefore, the reliability of the subsystem with a heterogeneous backup unit is

$$R_{s(1,2)} = R_1 + (1 - R_1)^* R_2 \quad (2\text{-}3)$$

and for three parallel components is

$$R_{s(1,2,3)} = R_{s(1,2)} + (1 - R_{s(1,2)})^* R_3 \quad (2\text{-}4)$$

Thus a general form would be

$$R_{s(1,2,3,\ldots,n)} = R_{s(1,2,\ldots,n-1)} + (1 - R_{s(1,2,\ldots,n-1)}) R_n \quad (2\text{-}5)$$

Suppose two tractors are in parallel to form some subsystem.
Let’s say that tractor 1 has a unit reliability of 0.90 and
unit 2 is 0.78 (Fig. 2-3). Using Eq. (3), the reliability calculation would be:

$$R_{s(1,2)} = R_1 + (1 - R_1) R_2$$

Assuming Tractor 1 is selected first,

$$R_{s(1,2)} = 0.9 + (1 - 0.9)^* 0.78 = 0.978$$

The dynamics of production agriculture systems can become quite complex. Tractors may back up several subsystems, performing several functions, or be unable to serve as backups because of incompatibility of components or unmatched horsepower requirements. Reliabilities seldom are identical. The best approach is to calculate reliabilities for each subsystem separately and then to combine the subsystem values to attain the complete system reliability.
Suppose farmer A had two enterprises: dairy and peanuts. To some extent, the two separate agricultural systems must share equipment, such as tractors. Farmer A must recognize the strengths and weaknesses of this arrangement. Let's analyze farmer A's peanut harvesting operation, as shown in the following table and Figure 2-4. Suppose it consists of a large tractor pulling a peanut combine. A wagon attached to the combine receives the peanuts. Another small tractor pulls the wagon away, empties the load and returns just in time to exchange wagons with the combine unit. The iterative process assumes that the unit of highest reliability is always used first. This is the usual management situation.
The calculations of each subsystem would be as follows:

Subsystem 1:

- Rss1 = 0.83 + 0.17 * (0.83)^3 = 0.9272

Subsystem 2:

- Rs(1,2) = 0.85 + (1 - 0.85) * 0.72 = 0.9580

Farmer A's System

Subsystem	Machinery available	Reliabilities
1	1 100-hp tractor dedicated to pulling combine	0.83 each

1	100-hp tractor backs up pulling unit, small tractor in subsystem 5, and tractor working at the dairy operation	
2	1 peanut combine	0.85
2	1 backup combine	0.72
3	1 wagon behind combine	0.90
4	1 wagon behind tractor	0.90
4	1 extra wagon to back up either subsystem 3 or 4	0.90
5	1 40-hp tractor to pull wagon	
6	1 40-hp tractor to pull wagon	

Note: The table provides information about the machinery available for each subsystem, along with their respective reliabilities.

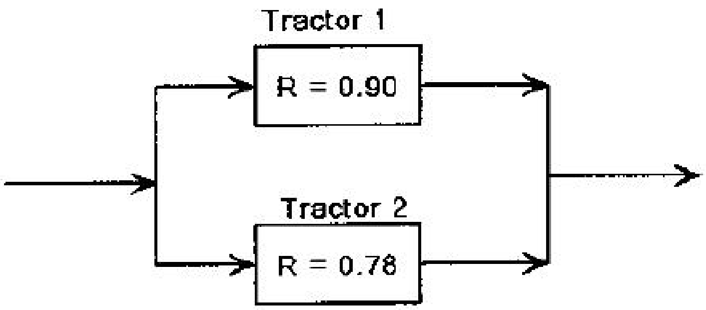


Figure 2-3 Heterogeneous parallel machines: $R = 0.90 + 0.10 * 0.78 = 0.978$.

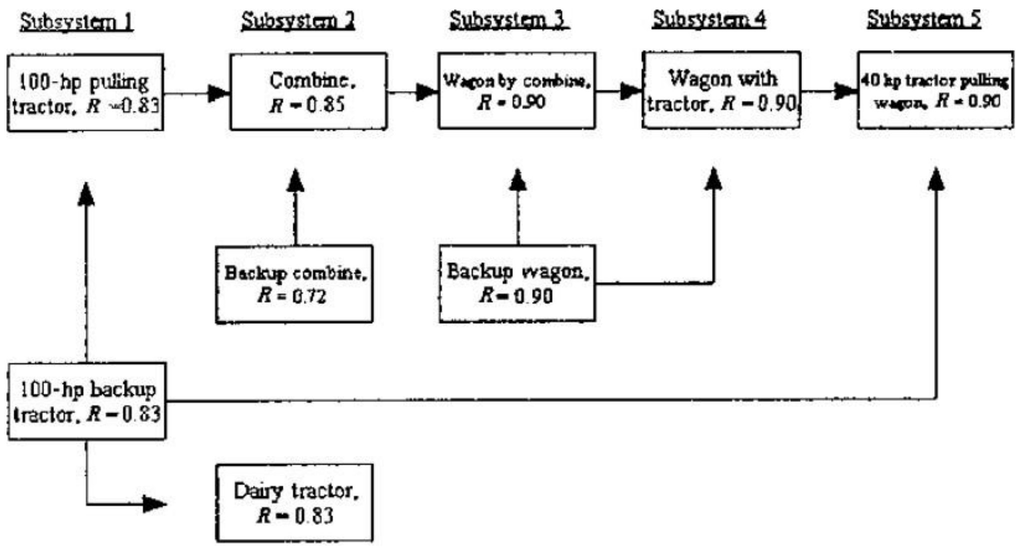


Figure 2-4 Peanut combine system with backups.

Subsystems 3 and 4. The added backup wagon is the same as having three wagons that must perform two functions. Thus, from Eq. (3):

$$R_{ss(3,4)} = 0.90 + 0.10(0.90)^2$$
$$= 0.9810$$

Subsystem 5. From Equation (3):

$$R_{ss(3,4)} = 0.83 + (1 - 0.83)*(0.83)^3$$
$$= 0.83 + 0.0972 = 0.9272$$

Total System. From Eq. (1):

$$R_{system} = 0.9272*0.958*0.9810*0.9272$$
$$= 0.8079$$

The iterative processes assume that the unit of highest reliability is always used first. In fact, one can see that doing otherwise might greatly diminish system reliability. The old philosophies of "I'll use the old ones first" and "I'll use the old ones 'until they wear out" simply do not pay.

Estimating Values of Individual Components

Just how does one attain the reliability values for machines, components, and functions? Absolutely the best way is to keep records on these units. Fortunately, computers and spreadsheet software make this task much easier today. Line foremen can record downtimes, as can mechanics or service managers. In the case of agricultural field machines, this is certainly "doable." One of the world's largest field production sugarcane growers actually tracks each field machine and keeps a life record via computer database. A farmer could keep uptime and downtime records on a spreadsheet.

In the case of processing plants, maintenance records often exist, and data estimates can be made by "recouping" the past information on items such as blenders, mixers, conveyors, bagging machines, and chemical processes. Where no life records exist, a good manager can collect sample data using good statistical techniques. Data can sometimes be gathered from other plants or the engineering firms producing the devices.

The literature in processing journals does contain some reliability data. And when all else fails, an ASM could interview users of the machines and processes to backtrack in time to find failures and downtimes. The real bottom line is that attaining accurate unit reliability data requires forward planning. However, the effort to attain the data will yield great rewards in system performance.

Estimating Human Component Values

Many situational factors affect human performance. Operator unit reliabilities can range from zero to 0.99999 reliability. It becomes quite difficult to develop generalized relationships. The trade-off considerations that can be applied are consequently qualitative. Costs, hazards, state of the technology, and other factors often influence the human role in an agricultural system. It was also shown that the reliability in a space system with a maintenance person available could be higher than that of the same system with automated devices as a monitor or "fail-safe" unit. Humans can seldom be rivaled by equipment. The following illustrates the trade-offs that exist with the use of humans.

Human long-term unit values seldom exceed 0.78. This is because there are so many time deductions one must make. Ignoring time lost for weekends and hours beyond 40 per week, the following lost time applies:

- Sick time
- Late time
- Vacation time
- Family leaves
- Strike time
- Break times
- Other

Humans are also subject to errors from repetitive tasks. The value assigned to human subjects varies greatly, depending on how they are inserted into the system. With proper managerial planning and backups, the values can be very high.

Let's take a closer look at the true value of a human in an agricultural system. Suppose a woman operates a bagging machine in a line operation that produces bags of garden mulch for the Super Duper market outlets. In a year, if she worked an eight-hour day, five days a week, she would need to be available 2080 hours per year. But she is not likely to be able to deliver this. Consider the following time losses:

Activity	Hours lost
2 weeks of vacation	80
Holidays (11 days)	88
Family leave (5 days)	40
[illegible]	43
[illegible]	50
[illegible]	56
	hours

$$\text{Total time lost (\%)} = \frac{457}{2080} \times 100 = 21.97\%$$

$$\text{Approximate reliability} = 78.03\%$$

The first reaction would be that this is unacceptable. But, this is just being human. It would be easy to develop a much worse scenario for an employee. So how does the plant manager cope with labor on a line that might involve 20 or more employees?

First, let's assume that the manager could back up this employee with another available employee. The manager might call in another qualified [1] individual off-shift. Or maybe there is a pool of employees available. The calculation would [2] be:

$$R_{\text{bagger}} = 0.7803 + 0.7803(1 - 0.7803) = 0.9517$$

We can see that by having a backup available raises the reliability of the human component to 95.17%.

Managerial Implications

The use of parallel or redundant units becomes a very important factor in production management decisions, such as deciding what unit to replace and whether to buy new or used equipment. Reliability and machinery labor costs are clearly traded off to attain some acceptable level of performance.

It becomes clear that the use of redundant subsystems is often more economical than simply purchasing new units with higher reliability. Comparisons between ownership and operating costs of new purchases versus several older units and their maintenance and repair operating costs are necessary. Leasing and rental units must also be considered. Individuals or corporations "starting out" or with limited capital obviously have some alternatives that may be quite viable.

The human operator can be used to great advantage. If inserted properly into a system, reliability can be increased several-fold to save capital outlay.

Weighing the Cost of Attaining System Reliability

One can come to the supposition very quickly that most systems must achieve a 0.95 total reliability or better to be considered "successful." There are almost always alternatives. And each alternative has its costs. The decision could be driven by how to get an acceptable system reliability for the lowest cost. Let's consider a struggling college graduate, Bob, desiring to farm. He owns an older combine of unit reliability of

0.88. He knows this is not good enough. So what are his alternatives?

Suppose his dad is willing to allow Bob to use his new combine of 0.96 reliability as a backup, but only when he is not combining himself. The calculation would be:

$$R_{\text{combining}} = 0.88 \times (1 - 0.88)0.96^2 = 0.9905$$

Now, if good old dad is generous and does not charge Bob, this is a no brainer. Use dad's combine as a backup! (See how much smarter dad is now?) Each method of backup could have another opportunity cost. Here are some other alternatives:

Alternative	Depreciation cost
Buy a new combine	$ 45,000
Purchase a used backup	15,000
Lease a new combine	35,000
Rent a backup	?
Hire a custom operator to harvest and sell the old combine	?
Steal a new combine (maybe you would not want to do this)	?

In a processing situation, some devices might be extremely expensive, such as a reactor in an ethanol processing plant. The backup alternative may be maintaining an extensive parts inventory or even an emergency contract with an engineering firm to perform immediate services.

Another alternative is to introduce the concept of scheduled repair versus maintenance. Suppose the huge sugarcane harvest system has hundreds of tractors. Based on past records, the managers may know what breaks down and when. They might actually shut down the operation of units with higher hours and rebuild the transmissions, hydraulics, and engines before they break down. This might be expensive and require a larger pool of tractors, but it might be cheaper than buying new units or stocking even more backup units.

This concept is often used in situations where downtime is either extremely expensive or critical (no one wants their army tank to break down during battle)! Or the grain elevator operation does not want the bucket elevator to break down during a key harvest period. In any case, the ASM needs to be a true thinker!

This type of evaluation and trade-off consideration should be ongoing. Arguably, reliability planning could be the most important agricultural systems decision—but the one most often neglected.

Simulation of Crop Growth and Field Operations

Definition: Crop growth simulation models are mathematical representations of the complex interactions between plants, the environment, and management practices. They simulate the growth and development of crops under various conditions, providing insights into potential yields, resource requirements, and the impact of different management strategies.

Key Components:

- **Plant Growth Models:** These models describe the physiological processes of plants, such as photosynthesis, respiration, and nutrient uptake. They incorporate factors like leaf area development, light interception, and dry matter accumulation.
  - **Example:** The CERES-Wheat model simulates the growth of wheat by considering factors like temperature, water availability, and nitrogen uptake.
- **Environmental Models:** These models simulate factors like temperature, precipitation, sunlight, and soil conditions that affect crop growth. They can be based on historical data, weather forecasts, or climate change projections.
  - **Example:** The EPIC (Environmental Policy Integrated Climate) model simulates the impact of climate change on crop yields in different regions.
- **Management Practices:** These models incorporate the effects of various agricultural practices, such as irrigation, fertilization, and pest control. They can be used to evaluate the impact of different management strategies on crop performance.
  - **Example:** The APSIM (Agricultural Production Systems Simulator) model can simulate the effects of different irrigation regimes on crop yields and water use efficiency.

Benefits:

- **Predicting Yields:** Simulate crop growth under different scenarios to estimate potential yields and identify the optimal management practices to maximize production.

- **Optimizing Resource Use:** Identify the optimal allocation of resources (water, fertilizer, pesticides) to maximize yields while minimizing costs and environmental impact.
- **Evaluating Management Strategies:** Assess the impact of different management practices on crop performance and sustainability. For example, simulate the effects of different tillage practices on soil erosion and crop yields.
- **Risk Assessment:** Evaluate the risks associated with climate variability and other uncertainties. For example, simulate the impact of drought or extreme weather events on crop production.

Example: A farmer is considering using a new irrigation system to improve crop yields. By using a crop growth simulation model, the farmer can simulate the impact of different irrigation regimes on crop growth and water use efficiency, helping them make an informed decision about whether to invest in the new system.

Growing degree-days (GDDs) are a measure of heat accumulation used to predict plant and pest development rates. They are calculated by adding up the daily average temperature (above a certain base temperature) over a period of time. GDDs can be used to estimate the date that a crop will reach maturity, when a pest will emerge from dormancy, or when a flower will bloom.

Here's a breakdown of the concept:

- **Base temperature:** This is the minimum temperature at which a plant or pest can begin to grow or develop. It varies among different species and can be affected by factors such as genetics and environmental conditions.
- **Daily average temperature:** This is the average of the maximum and minimum temperatures for a given day.
- **GDD calculation:** GDDs are calculated by subtracting the base temperature from the daily average temperature and adding up the values for each day. If the daily average temperature is below the base temperature, the GDD value is zero.

Here's an example of how to calculate GDDs:

- Base temperature for corn: 50°F
- Daily maximum temperature: 85°F
- Daily minimum temperature: 60°F
- Daily average temperature: (85°F + 60°F) / 2 = 72.5°F
- GDDs for that day: 72.5°F - 50°F = 22.5 GDDs

How GDDs are used:

- **Predicting crop maturity:** By tracking the accumulation of GDDs over the growing season, farmers can estimate when their crops will reach maturity and be ready for harvest.

- **Timing pest control:** GDDs can be used to predict the emergence of pests and time pesticide applications accordingly.
- **Selecting varieties:** GDDs can help farmers select varieties of crops that are well-suited to their local climate and growing season.
- **Monitoring plant health:** GDDs can be used to monitor the progress of plant growth and identify potential problems.

Limitations:

- GDDs are a simplified model of plant growth and do not account for all factors that can affect plant development.
- GDDs may not be accurate for plants that are stressed by environmental conditions or other factors.
- GDDs may vary depending on the specific location and microclimate.

Overall, GDDs are a valuable tool for farmers and agricultural researchers. By understanding how to calculate and use GDDs, farmers can make more informed decisions about crop management and improve their yields.

$$\text{GDDs per day} = (T_{\text{max}} + T_{\text{min}})/2 - 50$$

Optimizing the Use of Resources

Definition: Resource optimization involves allocating available resources (e.g., land, water, labor, capital) in the most efficient way to achieve desired objectives, such as maximizing profit or minimizing costs.

Key Techniques:

- **Linear Programming:** A mathematical optimization technique used to allocate limited resources to maximize or minimize a linear objective function subject to linear constraints. It is suitable for problems with a single objective and linear relationships between variables.
    - **Example:** A farmer wants to maximize profit by planting two crops, corn and soybeans. The farmer has 100 acres of land available and a limited budget for fertilizer. The profit per acre for corn is $100, and for soybeans is $80. The fertilizer requirements for corn are 2 units per acre, and for soybeans are 1 unit per acre. The total available fertilizer is 150 units. The farmer can use linear programming to determine the optimal allocation of land between corn and soybeans to maximize profit.
- **Nonlinear Programming:** A more general optimization technique that can handle nonlinear relationships between variables. It is suitable for problems with multiple objectives or nonlinear constraints.
    - **Example:** A farmer wants to minimize the cost of irrigation while maintaining

a certain level of crop yield. The cost of irrigation may be a nonlinear function of the amount of water applied, and the crop yield may also be a nonlinear function of water availability. Nonlinear programming can be used to find the optimal irrigation schedule.

- **Dynamic Programming:** A technique for solving optimization problems that involve sequential decisions. It is suitable for problems where decisions made at one time period affect the outcomes of decisions made in subsequent periods.
  - **Example:** A farmer wants to determine the optimal timing of fertilizer applications throughout the growing season to maximize crop yield. Dynamic programming can be used to consider the impact of fertilizer applications at different stages of crop growth.

Applications:

- **Crop Allocation:** Determining the optimal mix of crops to grow on a given piece of land, considering factors such as soil type, climate, market demand, and profitability.
- **Irrigation Scheduling:** Optimizing irrigation water use to maximize crop yields while minimizing water wastage and environmental impact.
- **Fertilizer Management:** Determining the optimal amount and timing of fertilizer application to maximize crop yields and minimize nutrient losses.
- **Machinery Allocation:** Assigning machinery to tasks in a way that maximizes efficiency and minimizes costs.
- **Farm Management:** Optimizing the overall management of a farm to maximize profitability and sustainability.

Linear Programming

Definition: Linear programming is a mathematical optimization technique used to find the optimal solution to a problem with a linear objective function and linear constraints.

Basic Components:

- **Objective Function:** The function to be maximized or minimized.
- **Decision Variables:** The variables that can be adjusted to optimize the objective function.
- **Constraints:** The limitations or restrictions on the decision variables.

Example:

- **Problem:** A farmer wants to maximize profit by planting two crops, corn and soybeans. The farmer has 100 acres of land available and a limited budget for fertilizer. The profit per acre for corn is $100, and for soybeans is $80. The fertilizer requirements for corn are 2 units per acre, and for soybeans are 1 unit per acre. The total available fertilizer is 150 units.

- **Linear Program:**
  - Maximize Profit = 100Corn + 80Soybeans
  - Subject to:
    - Corn + Soybeans <= 100 (land constraint)
    - 2*Corn + Soybeans <= 150 (fertilizer constraint)
    - Corn, Soybeans >= 0 (non-negativity constraint)

Solution:

The optimal solution is to plant 50 acres of corn and 50 acres of soybeans, which will result in a maximum profit of $9000.

Project Scheduling

Definition: Project scheduling involves planning, organizing, and coordinating tasks to ensure that a project is completed on time and within budget.

Key Techniques:

- **Gantt Charts:** Visual representations of project timelines, showing the duration of each task and their dependencies. They are useful for tracking project progress and identifying potential bottlenecks.
  - **Example:** A Gantt chart for a construction project would show the duration of each phase of the project, such as site preparation, foundation work, framing, and finishing.
- **Network Diagrams:** Graphical representations of project activities and their relationships, often using the Critical Path Method (CPM) to identify the critical path (the sequence of tasks that determine the project's overall duration).
  - **Example:** A network diagram for a crop production project would show the sequence of tasks, such as planting, irrigation, fertilization, and harvesting. The critical path would be the longest sequence of tasks that must be completed before the project can be finished.
- **PERT (Program Evaluation and Review Technique):** A probabilistic network analysis technique that considers the uncertainty in task durations. It is useful for projects with uncertain task times.
  - **Example:** A PERT chart for a research project would show the estimated duration of each task, along with the optimistic, most likely, and pessimistic estimates.

Applications:

- **Construction Projects:** Planning and managing the construction of buildings, infrastructure, or other projects.
- **Agricultural Operations:** Scheduling planting, harvesting, and other agricultural activities.

- **Research Projects:** Organizing and coordinating research tasks to ensure timely completion.

Artificial Intelligence and Decision Support Systems

Definition: Artificial intelligence (AI) refers to the development of intelligent agents that can reason, learn, and solve problems. Decision support systems (DSS) are computer-based systems that help decision-makers analyze data and make informed decisions.

Applications in Agriculture:

- **Crop Yield Prediction:** Using AI algorithms to predict crop yields based on historical data, weather forecasts, and other factors. This can help farmers make better decisions about planting, harvesting, and marketing.
- **Pest and Disease Management:** Employing AI to detect and identify pests and diseases early, enabling timely intervention to prevent crop damage.
- **Precision Agriculture:** Using AI-powered technologies (e.g., drones, sensors) to collect data on crop health, soil conditions, and other factors to optimize resource management. This can help farmers use resources more efficiently and reduce their environmental impact.
- **Decision Support Systems:** Developing DSS to help farmers make informed decisions about planting, harvesting, marketing, and other agricultural activities. DSS can provide farmers with access to relevant data, analytics tools, and expert advice.

Key AI Techniques:

- **Machine Learning:** Algorithms that allow computers to learn from data and improve their performance over time. For example, machine learning can be used to develop models that predict crop yields based on historical data.
- **Natural Language Processing:** Enabling computers to understand and respond to human language. This can be used to develop chatbots that can answer farmers' questions about agricultural practices.
- **Computer Vision:** Algorithms that allow computers to interpret and understand visual information. This can be used to develop systems that can automatically identify weeds or detect plant diseases from images.

Example: A farmer can use a DSS to analyze weather data, soil information, and crop prices to determine the optimal planting date for a particular crop. The DSS can also provide recommendations for fertilizer application, irrigation scheduling, and pest control.

Artificial Intelligence:

Benefits of AI in agriculture

Until recently, using the words AI and agriculture in the same sentence may have seemed like a strange combination. After all, agriculture has been the backbone of human civilization for millennia, providing sustenance as well as contributing to economic development, while even the most primitive AI only emerged several decades ago. Nevertheless, innovative ideas are being introduced in every industry, and agriculture is no exception. In recent years, the world has witnessed rapid advancements in agricultural technology, revolutionizing farming practices. These innovations are becoming increasingly essential as global challenges such as climate change, population growth together with resource scarcity threaten the sustainability of our food system. Introducing AI solves many challenges and helps to diminish many disadvantages of traditional farming.

Data-based decisions

The modern world is all about data. Organizations in the agricultural sector use data to obtain meticulous insights into every detail of the farming process, from understanding each acre of a field to monitoring the entire produce supply chain to gaining deep inputs on yields generation process. AI-powered predictive analytics is already paving the way into agribusinesses. Farmers can gather, then process more data in less time with AI. Additionally, AI can analyze market demand, forecast prices as well as determine optimal times for sowing and harvesting.

Artificial intelligence in agriculture can help explore the soil health to collect insights, monitor weather conditions, and recommend the application of fertilizer and pesticides. Farm management software boosts production together with profitability, enabling farmers to make better decisions at every stage of the crop cultivation process.

Cost savings

Improving farm yields is a constant goal for farmers. Combined with AI, precision agriculture can help farmers grow more crops with fewer resources. AI in farming combines the best soil management practices, variable rate technology, and the most effective data management practices to maximize yields while minimizing minimize spending.

Application of AI in agriculture provides farmers with real-time crop insights, helping them to identify which areas need irrigation, fertilization, or pesticide treatment. Innovative farming practices such as vertical agriculture can also increase food production while minimizing resource usage. Resulting in reduced use of herbicides, better harvest quality, higher profits alongside significant cost savings.

Automation impact

Agricultural work is hard, so labor shortages are nothing new. Thankfully, automation provides a solution without the need to hire more people. While mechanization transformed agricultural activities that demanded super-human sweat and draft animal labor into jobs that took just a few hours, a new wave of digital automation is once more revolutionizing the sector.

Automated farm machinery like driverless tractors, smart irrigation, fertilization systems, IoT-powered agricultural drones, smart spraying, vertical farming software, and AI-based greenhouse robots for harvesting are just some examples. Compared with any human farm worker, AI-driven tools are far more efficient and accurate.

Applications of artificial intelligence in agriculture

Traditional farming involves various manual processes. Implementing AI models can have many advantages in this respect. By complementing already adopted technologies, an intelligent agriculture system can facilitate many tasks. AI can collect and process big data, while determining and initiating the best course of action. Here are some common use cases for AI in agriculture:

Optimizing automated irrigation systems

AI algorithms enable autonomous crop management. When combined with IoT (Internet of Things) sensors that monitor soil moisture levels and weather conditions, algorithms can decide in real-time how much water to provide to crops. An autonomous crop irrigation system is designed to conserve water while promoting sustainable agriculture and farming practices. AI in smart greenhouses optimizes plant growth by automatically adjusting temperature, humidity, and light levels based on real-time data.

Detecting leaks or damage to irrigation systems

AI plays a crucial role in detecting leaks in irrigation systems. By analyzing data, algorithms can identify patterns and anomalies that indicate potential leaks. Machine learning (ML) models can be trained to recognize specific signatures of leaks, such as changes in water flow or pressure. Real-time monitoring and analysis enable early detection, preventing water waste together with potential crop damage.

AI also incorporates weather data alongside crop water requirements to identify areas with excessive water usage. By automating leak detection and providing alerts, AI technology enhances water efficiency helping farmers conserve resources.

Crop and soil monitoring

The wrong combination of nutrients in soil can seriously affect the health and growth of crops. Identifying these nutrients and determining their effects on crop yield with AI allows farmers to easily make the necessary adjustments.

While human observation is limited in its accuracy, computer vision models can monitor soil conditions to gather accurate data necessary for combatting crop diseases. This plant science data is then used to determine crop health, predict yields while flagging any particular issues. Plants start AI systems through sensors that detect their growth conditions, triggering automated adjustments to the environment.

In practice, AI in agriculture and farming has been able to accurately track the stages of wheat growth and the ripeness of tomatoes with a degree of speed and accuracy no human can match.

Detecting disease and pests

As well as detecting soil quality and crop growth, computer vision can detect the presence of pests or diseases. This works by using AI in agriculture projects to scan images to find mold, rot, insects, or other threats to crop health. In conjunction with alert systems, this helps farmers to act quickly in order to exterminate pests or isolate crops to prevent the spread of disease.

AI technology in agriculture has been used to detect apple black rot with an accuracy of over 90%. It can also identify insects like flies, bees, moths, etc., with the same degree of accuracy. However, researchers first needed to collect images of these insects to have the necessary size of the training data set to train the algorithm with.

Monitoring livestock health

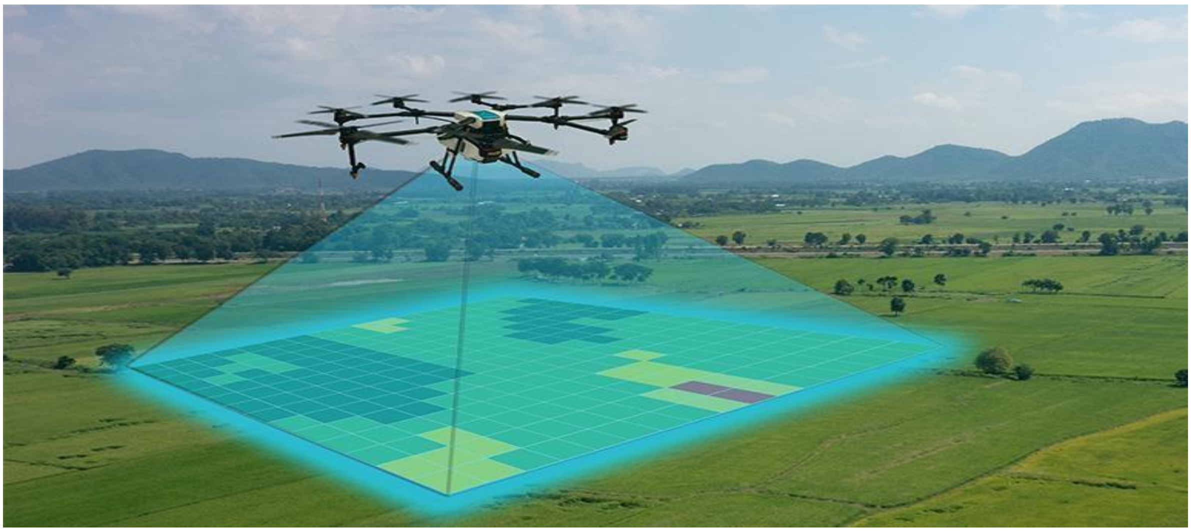
It may seem easier to detect health problems in livestock than in crops, in fact, it's particularly challenging. Thankfully, AI for farming can help with this. For example, a company called CattleEye has developed a solution that uses drones, cameras together with computer vision to monitor cattle health remotely. It detects atypical cattle behavior and identifies activities such as birthing.

CattleEye uses AI and ML solutions to determine the impact of diet alongside environmental conditions on livestock and provide valuable insights. This knowledge can help farmers improve the well-being of cattle to increase milk production.

Intelligent pesticide application

By now, farmers are well aware that the application of pesticides is ripe for optimization. Unfortunately, both manual and automated application processes have notable limitations. Applying pesticides manually offers increased precision in targeting specific areas, though it might be slow and difficult work. Automated pesticide spraying is quicker and less labor-intensive, but often lacks accuracy leading to environment contamination.

AI-powered drones provide the best advantages of each approach while avoiding their drawbacks. Drones use computer vision to determine the amount of pesticide to be sprayed on each area. While still in infancy, this technology is rapidly becoming more precise.



Yield mapping and predictive analytics

Yield mapping uses ML algorithms to analyze large datasets in real time. This helps farmers understand the patterns and characteristics of their crops, allowing for better planning. By combining techniques like 3D mapping, data from sensors and drones, farmers can predict soil yields for specific crops. Data is collected on multiple drone flights, enabling increasingly precise analysis with the use of algorithms.

These methods permit the accurate prediction of future yields for specific crops, helping farmers know where and when to sow seeds as well as how to allocate resources for the best return on investment.

Automatic weeding and harvesting

Similar to how computer vision can detect pests and diseases, it can also be used to detect weeds and invasive plant species. When combined with machine learning, computer vision analyzes the size, shape, and color of leaves to distinguish weeds from crops. Such solutions can be used to program robots that carry out robotic process automation (RPA) tasks, such as automatic weeding. In fact, such a robot has already been used effectively. As these technologies become more accessible, both weeding and harvesting crops could be carried out entirely by smart bots.

Sorting harvested produce

AI is not only useful for identifying potential issues with crops while they're growing. It also has a role to play after produce has been harvested. Most sorting processes are traditionally carried out manually however AI can sort produce more accurately.

Computer vision can detect pests as well as disease in harvested crops. What's more, it can grade produce based on its shape, size, and color. This enables farmers to quickly separate produce into categories — for example, to sell to different customers at different prices. In comparison, traditional manual sorting methods can be painstakingly labor-intensive.

Surveillance

Security is an important part of farm management. Farms are common targets for burglars, as it's hard for farmers to monitor their fields around the clock. Animals are another threat — whether it's foxes breaking into the chicken coop or a farmer's own livestock damaging crops or equipment. When combined with video surveillance systems, computer vision and ML can quickly identify security breaches. Some systems are even advanced enough to distinguish employees from unauthorized visitors.

AI and its Application

The concept of expert systems, artificial intelligence, ''fuzzy logic,'' and knowledge-based decision support systems (information systems) was accepted rapidly in business and industry. Production control systems in factories have included these concepts so that operating problems, such as bad welds, can be either prevented or fixed much more quickly than under simpler control systems.

Robotics

Robotics has been considered a part of the overall field of artificial intelligence by many authors. A robot is not just an automatic welding machine on a car body production line, but a machine that can be programmed to do a variety of tasks and that can interact with its environment. A robot may need to make a decision about whether an object that it must select is a nut or a bolt, a green tomato or a ripe, red tomato. Thus robots need to ''see,'' recognize objects, and make decisions, so they need intelligence 'artifi cial'' intelligence.

Natural Language

For easier and greater application of the computer in our working world, we need better and more natural ways for hu- mans to communicate with the computer. The computer needs to be shown more about how we communicate so that we can spend less time learning how the computer communicates. This is a difficult field, but progress is being made. The programs that can process natural language sentences must determine which words are the noun, the verb, and the object, In addition, voice recognition by the computer is a part of this, because we often do not want to or are unable to type our input, but should speak to the computer. The development of programs that understand human natural language is a vital part of the whole artificial intelligence investigation, because this requires intelligence. We are going no further into this area.

Fuzzy Logic

To simulate human intelligence, artificial intelligence must be able to handle more than just numbers, yet the heart of any computer is just a very fast processor of data in binary form, zeros and ones. Our programming languages, such as FORTRAN, C++, and Java, have allowed us to program computers with English words and mathematical symbols, yet most programs are very precise and objective in their results. They usually produce a table of numbers, and they can rank these results numerically, evenwith huge numbers of possibilities.

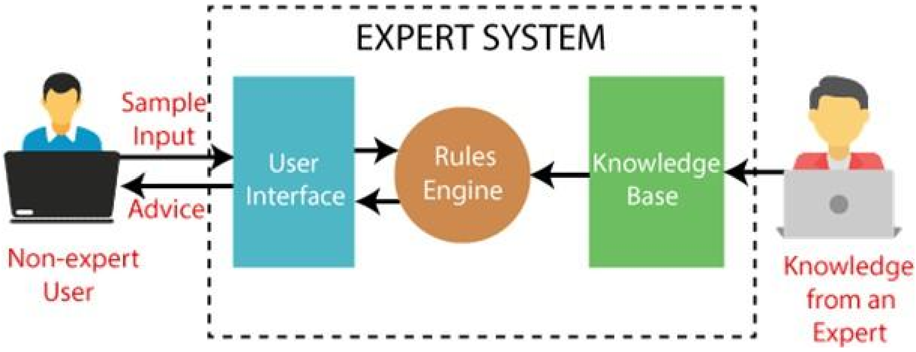
But humans often must make decisions in which the input data and the resulting output are not in neat mathematical or completely logical form. For example, a computer using a linear programming algorithm can select the one best combination of several ingredients that will result in the lowest-cost feed mixture that meets the specifications in terms of protein, fat, fiber, and total digestible nutrients from among an almost infinite number of possible combinations. However, until artificial intelligence, the computer could not solve less precise problems, such as determining the most profitable combination of crops to plant for the coming year, with prices and costs being uncertain. And managers often want a recommendation in terms somewhat like a weather forecast, such as, ''If you do not spray, chances are about

1 in 5 that the disease will cause more damage than the spraying cost.''

Expert Systems

An expert system simulates a human expert in a narrow subject matter domain. For example, to develop an expert system program to give soybean growers advice about insect problems like a consulting entomologist might give, the program needs to do the following:

1. Ask the grower some general questions to find out what the problem is.
2. Find out the farm's location, variety of soybeans, stage of growth, identification, or description of the bugs.
3. Finally, give the best estimate the system can on the type of insect, whether or not treatment is needed at this time, and when and what type of insecticide is recommended if treatment is needed.



Programs such as these probably will not replace the consultant, but they will be used by the consultant to give better advice and probably to produce good printed reports for the client. Many agricultural expert systems are diagnostic in nature, such as the example just given. In addition, expert systems may be (and a few have been) developed for making technical management decisions, such as purchase of new equipment, deciding on a crop rotation, making a marketing plan for grain, or culling livestock from a breeding herd.

Knowledge-Based Decision Support Systems

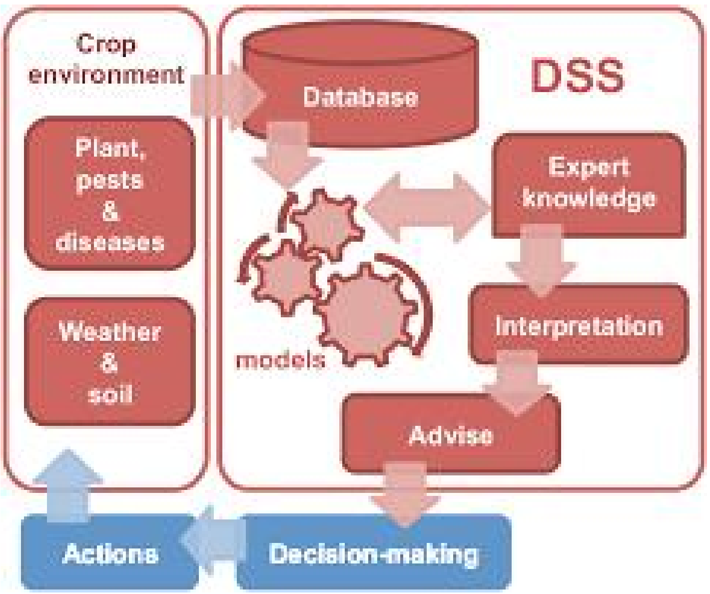
The term knowledge-based decision support systems (or decision support systems) includes expert systems but covers a broader range of program types .Often it would be advantageous. for an expert system to have available the latest data from the commodity futures market or cash markets or to be able to run a simulation program with current weather data to get crop yield estimates in order to give the user the best up-to- date expert advice. When an expert system uses a database, a spreadsheet, or some other external program, such as a simulation program, the whole integrated system is referred to as a decision support system. An expert system is also a knowledge- based decision system or decision support system, because it contains the knowledge of the expert and it helps, or supports, the user in making a decision.

The word support emphasizes the important idea that the computer is not controlling the decision. It is not the decision maker. It helps (supports) the human decision maker by keeping track of many factors, whereas the decision maker is also likely taking into account other factors, especially more subjective ones. A citrus production manager in Florida makes a very sound point about the use of computers in management: ''Use the computer for what it can do best, calculating and remembering lots of data, and use the human for what the person can do best, integrating the output of the decision sup- port system and other factors, including the human's experience, and come to a decision based on all these things.''

More recently, a broader common term has come to include decision support systems: information systems; the field has become known as information technology (IT).

Models of Decision Support system

Eg: Decision support system for crop disease.



Decision Support System Applications

Potential applications are innumerable, but many of them will fit under one of the following types.

- Diagnostics
- Marketing
- Systems operations management
- Automatic control
- Strategic planning

Static and Dynamic Decision Support Systems

Especially for agricultural systems, the idea of dynamic vs. static decision support systems is important for the development and operation of these systems. Static systems are those that are used, usually, at a single point in time; and each use is a new one, keeping no information from the last time it was used or ‘‘run.’’ A diagnostic system telling the user with a poor- looking crop what the problem is—disease, some nutrient lacking, drought, etc.—is a typical static system. An early ex- ample of such a system was used to identify soybean insect problems and recommend treatment.

However, many agricultural problems may be used throughout a growing season. Once the user enters data about the crop to assess the threat of an early-season disease, for example, the user may want to do it a week later to check on the same disease or on a question such as irrigation needs. These subsequent uses can take advantage of the earlier data entered to give decision support based on the history of the crop up to that point. These programs are called dynamic decision sup- port systems, and they must keep earlier data from one use to the next.