1. Yield Potential and Yield Gaps

Yield potential is defined as the yield of a crop cultivar when grown in environments to which it is adapted, with nutrients and water non-limiting, and pests and diseases effectively controlled (Evans, 1993). Hence, for a given crop variety or hybrid in a specific growth environment, yield potential is determined by the amount of incident solar radiation, temperature, and plant density—the latter determining the rate at which the leaf canopy develops under a given solar radiation and temperature regime. The difference between yield potential and the actual yield represents the exploitable yield gap (Fig. 1.1). Hence, genotype, solar radiation, temperature, plant population, and degree of water deficit determine water-limited yield potential. In addition to yield reduction from limited water supply, actual farm yields are determined by the magnitude of yield reduction or loss from other factors such as nutrient deficiencies or imbalances, poor soil quality, root and/or shoot diseases, insect pests, weed competition, water logging, and lodging.

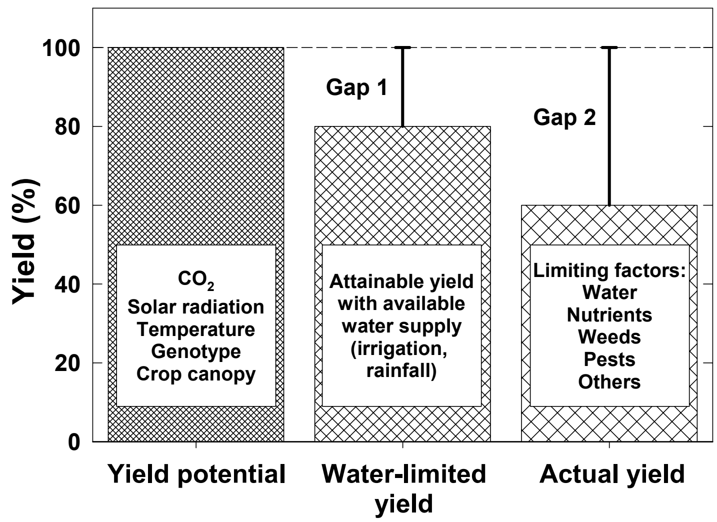


Figure 1.1. Conceptual framework of yield potential, water-limited yield potential, and actual farm yields as constrained by a number of production factors (Cassman et al., 2003).

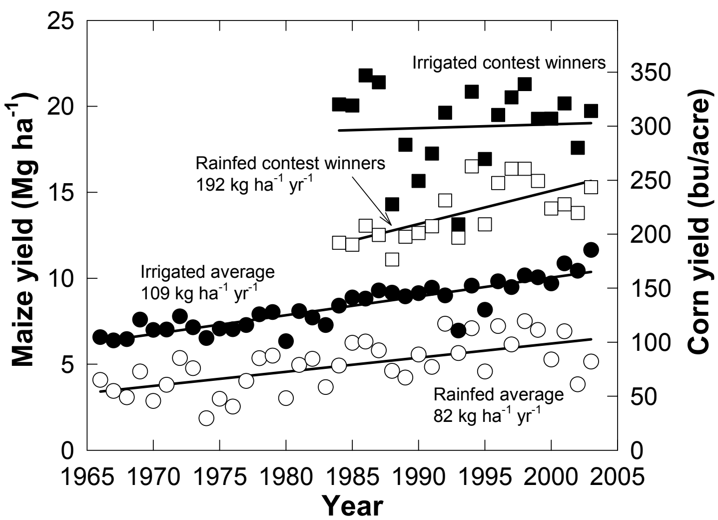
Management decisions such as hybrid selection, planting date, and plant density can affect the yield potential at a given site by influencing the utilization of available solar radiation and soil moisture reserves during the growing season. Yield potential also fluctuates somewhat from year to year (typically ±10-15%) because of normal variation in solar radiation and temperature regime. To achieve yield potential, the crop must be optimally supplied with water and nutrients and completely protected against weeds, pests, diseases, and other factors that may reduce growth. Such conditions are rarely achieved under field conditions, nor is it likely to be cost-effective for farmers to strive for such perfection in management. Instead, understanding site yield potential and its normal year-to-year variation can help identify management options and input requirements that combine to reduce the size of the exploitable yield gap while maintaining profitable and highly efficient production practices.

For much of the U.S. Corn Belt, available moisture is the most important growth-limiting factor. The water deficit is determined by factors such as soil water holding capacity, rainfall, irrigation, and evapotranspiration, which vary from site to site and year to year. Because irrigation can help ensure adequate water supply in the face of suboptimal rainfall, differences between yield potential and water-limited yield (yield gap 1 in Fig. 1.1.) are smaller and less variable in irrigated systems compared to rainfed maize systems.

In well-managed irrigated maize, the attainable water-limited yield is close to the yield potential ceiling and relatively stable from year to year because irrigation is provided during key growth stages to make up for water deficits. Management can therefore focus on providing sufficient nutrients to fully exploit attainable yield and on minimizing yield-reducing factors that determine yield gap 2 shown in Fig. 1.1. In rainfed maize, the attainable water-limited yield is typically less than that for irrigated maize, but fluctuates widely, depending on the initial soil moisture status, soil water holding capacity, planting date, plant density, evapotranspiration, and rainfall during the growing season. Therefore, setting a realistic yield goal is more difficult in rainfed (also called dryland agriculture) than under irrigated conditions because both yield gaps 1 and 2 can vary greatly from site to site or year to year.

Maximum yields obtained in yield contests or in well-managed research experiments provide the best estimates of yield potential because maize is grown at high plant density with optimal water and nutrient supply, and effective control of weeds, diseases, and insect pests. For example, in the past 20 years yield levels achieved by winners of the irrigated maize contest in Nebraska have averaged 300 bu/acre (18.8 Mg/ha), with a standard deviation of ±38 bu/acre among years (13%), which indicates the effect of growing season weather on the yield potential (Fig. 1.2).

Figure 1.2. Yield trends of irrigated and rainfed maize in Nebraska, comparing statewide average yields with yields obtained by the winners of the annual corn yield contest organized by the National Corn Growers Association (NCGA).



The extremes in yield potential are represented by low-yield years of 1993 (210 bu/acre, wet and cold) and 1988 (228 bu/acre, dry and hot) versus highest yields in 1986 (348 bu/acre) and 1998 (338 bu/acre) when temperatures and solar radiation supported high yield potential. During the same period, yields achieved by the winners of the rainfed maize contest in Nebraska have averaged 220 bu/acre (13.8 Mg/ha) but are steadily increasing such that maximum rainfed yields are now reaching 250 bu/acre in years with favorable weather. These numbers illustrate the typical upper limits of yield potential and water-limited rainfed maize yield in Nebraska.

The Hybrid-Maize model simulates maize growth on a daily basis from emergence to physiological maturity. This version of the program simulates maize yield potential and/or water limited yield, both assuming optimal nutrient supply and no yield losses from other factors (Fig. 1.1). For simulation of yield potential, the model requires *daily* weather data for solar radiation and maximum and minimum temperatures. For simulation of the water-limited rainfed or irrigated yield at a given site with optimal nutrient supply, the model requires *daily* weather data for solar radiation, maximum and minimum temperature, rainfall, reference evapotranspiration, and relative air humidity, as well as basic soil information influencing available water status such as soil textural class and bulk density.