A producer can monitor input use efficiency by following the cost of production per bushel. Optimum input mix efficiency and maximum profit are associated with the position where **cost per bushel is minimized**. A producer is justified in adding further inputs as long as the cost per bushel continues downward in response. Optimum input mix is attained when inputs are added up to the point where **marginal cost equals marginal revenue** (the last dollar of input cost returns only one dollar in additional revenue).

Yes. Over the long run, a producer who is watching their input costs as noted in question 1 above, will be adding optimal input levels and avoiding excessive input levels or abusive practices which may prove harmful to the environment or to the long term productive potential of the soil. In addition, effective management of productive fields leaves other, less productive areas out of production and in alternative uses for which they are better suited (e.g. pasture, wildlife refuge, etc.). Example: efficient utilization of applied N fertilizer (as influenced by the timing and rate of application) also means low levels of nitrate leaching into the groundwater. In addition, other less productive acres which would require greater inputs per bushel produced, may then be left out of production.

**GPS** is an acronym for "Global Position System" and commonly refers to the use of satellites and differential correction signals to provide time-stamped information pertaining to latitude, longitude and elevation. Varying levels of precision are available. **GIS** is an acronym for "Geographic Information System" and refers to the acquisition and GPS based spatial mapping of a wide range of data. **VRT** is an acronym for "Variable Rate Technology" and refers to the application of variable rates of a crop input as determined by position relative to accurately-mapped spatial data (such as soil type boundaries within a field).

**Example:** GPS determines the position of a combine as it moves through a field. GIS monitors and maps yield data relative to discrete positions within the field. VRT could be used to vary the amount of maintenance P or K fertilizer applied site-specifically within the field to reflect differing historical yield levels.

**a) Soil type** (as denoted on soils maps and visually by color, texture, slope, drainage).

**b) Prior management** Records are used to indicate prior management differences within a field. These might include differences in yield, prior ownership, crop rotation, etc.

Once a field's yield and soil test level histories are established, areas of similarly productive soils with a history of equivalent soil test levels and yields can be consolidated for representative sampling as units or unique management zones).

2 pts 5.  
- a) 8 inches
- b) 8 inches

4 pts 6.  
- a) 15 ppm
- b) \((15 \text{ ppm} - 9 \text{ ppm}) \times 5 = 30 \text{ pounds P}_{205} / \text{acre}\)

4 pts 7.  
- a) \(75 + (2.5 \times \text{ C.E.C.}) = 75 + (2.5 \times 10) = 75 + 25 = 100 \text{ ppm}\)
- b) \((\text{Critical Level } 100 \text{ ppm} - \text{Soil Test Level } 80 \text{ ppm}) \times [1 + (0.05 \times \text{ CEC } 10)] = (20) \times [1.5] = 30 \text{ pounds K}_{20} / \text{ acre}\)

2 pts 8.  
- a) Critical Level 15 ppm + Range 15 = 30 ppm
- b) Critical Level 100 ppm + Range 30 = 130 ppm
c) At the Economic Goal (Critical Level) there remains a 10 to 40% probability of yield response to additional P and/or K fertilizer application. However, even though yield level may climb in some years in response to higher soil test levels, other factors such as rainfall amount and distribution, delayed planting date, abnormally cold or hot temperature, disease and insect pressure etc. may be more limiting than soil fertility in a given year. In light of these other potentially yield limiting factors it would not pay (cost per bushel would be high) were a manager to fertilize at the never limiting level.

9. Primary symptoms are indicative of direct cause and effect relationships (e.g. hail impact on a corn leaf results in leaf tearing and tissue removal).

Secondary symptoms are indicative of indirect cause and effect relationships (e.g. plant twisting and stunting as leaves are unable to unfurl from the whorl after an earlier hail impact).

10. The line transect method measures percent surface cover (by residue).

The measurement is conducted by observing the percent of regularly spaced points (e.g. the foot interval marks on a measuring tape or evenly spaced knots on a knotted rope) which are in direct visual contact with surface residue on a line laid on the soil surface at a 45 degree angle to the previous crop's row direction.

11. No-till systems will typically demonstrate higher bulk density (initial tillage lessens bulk density for the first few weeks of the season), lower temperature (insulating blanket of residue retains low soil temperature and residue reflects warming sunlight away), and higher moisture (less evaporative loss under residue means wetter, cooler conditions) near the surface (where young roots are forming) vs. a conventionally-tilled system.

All of these factors result in less total root growth and a more shallow placement of root growth in the no-till system.

12. a) Latitude, previous crop residue, and soil drainage all influence soil temperature, which is critical in determining early season corn crop growth rate. Any one or a combination of northern latitude, heavy crop residue and poor soil drainage could result in cool conditions would slow crop growth and lower yield potential.

b) An example would be Coulter planted (no-till) corn at a northern Indiana location where the soil is poorly drained, corn is following high yield corn (so here is heavy non-fragile surface residue), and there is an early planting date in an unusually cool spring.

c) Possible management in this case would include improvement in soil drainage, rotate corn after soybeans to lessen surface residue at planting or use zone (strip) tillage and/or row residue removal in the fall. One may also use starter fertilizer at plant (or zone placement of P and K fertilizer if zone tillage is used) to provide greater access to applied P and K where roots are restricted in growth.

13. a) Reduced yield
b) Decreased height
c) Delayed maturity
d) Tabled (horizontal) roots
e) Visible nutrient deficiency symptoms
f) Heightened drought stress
g) Increased sensitivity to herbicide injury
h) Slowed infiltration of water (surface ponding, evidence of poor drainage such as mottled color or slow crop residue decomposition)
i) High bulk density as reflected by resistance to soil probe or knife
j) Surface crusting indicates shallow compaction resulting from heavy rainfall
k) Seedling lateral roots restricted to seed slot (sidewall compaction).

4 pts 14. Prevention
a) Provide adequate drainage (install or repair surface and subsurface drainage).
b) Stay off of wet fields.
c) Reduce primary and secondary tillage where possible.
d) Use lighter equipment or improved flotation tires on existing equipment (e.g. grain carts).
e) Unload at field ends (and unload partial hoppers) when soils moist.

Correction:
a) Deep vertical tillage in dry years (shatter compacted layer).
b) Include small grains and/or forages in rotation where practical.
c) Natural freeze-thaw cycles are shallow and generally ineffective in lessening soil compaction in the root zone.
d) Natural shrink-swell (seasonal dry/wet cycling), natural earthworm activity, and root growth will lessen deep compaction over time in soils where primary tillage has been reduced or eliminated.

5 pts 15. a) Shallow rooting and poor root uptake of mineral nutrition
b) Increased soil compaction potential
c) Delayed planting
d) Delayed harvest
e) Late-season drought stress
f) Non-uniform herbicide incorporation
g) Potential delay in field access for post-emergence herbicide application
h) Greater N losses to denitrification

2 pts 16. a) Typical depth of subsurface tile placement is 3 to 4 feet so drainage can be effective through the likely full depth of the corn root zone.

3 pts b) Mottling of gray interspersed with rust color in the top 13 to 18 inches of a soil profile indicates poor drainage critically high in the root zone. The gray color is evidence of prolonged water-logged conditions which results in the reduced (gray) form of Iron. Soil with a predominantly bright rust color indicates the presence of better drained conditions since the Iron is present in the oxidized (rust-colored) form iron.

- Yield map indicates a pattern of high yield nearest tile laterals and lower yield elsewhere, particularly in a wet growing season.
- Persistent surface wetness / ponding visible on nearly level soil.
- Slow warming of surface soil.
- Shallow root development not only associated only with compaction.
- Increased compaction.
- Delayed / stunted crop growth.

BONUS Targeting P and K soil fertility at or just above the Critical Level (Economic Goal) should provide sufficient P and K in most situations with normal levels of year to year variation in yield. However, in exceptionally productive management zone situations, yield may be seen to be consistently high across years (e.g. where there is good water holding capacity yet excellent soil drainage, no compaction so the root zone is deep, etc.). In such a situation the potential for factors other than P and K fertility to be most limiting to yield is reduced so a crop manager may indeed find economic response to higher than Critical Levels of P and K near the upper end of but still within the Maintenance Plateau. Multi year field testing of this potential for economic response would be in order in such exceptional cases.