GEOL 408/508

PRACTICAL NUTRIENT MANAGEMENT

Chapter 16

Brady and Weil, Rev. 14th Ed.

GOALS OF NUTRIENT MANAGEMENT-1

Nutrient management aims to achieve the following goals:

1. Cost-effective production of high-quality plants
2. Efficient use & conservation of nutrient resources
3. Maintenance or enhancement of soil quality
4. Protection of the environment beyond the soil

Plant production:

- three primary types:
  - agriculture: need to increase plant yields
  - forestry: tree production; wildlife habitat
  - ornamental landscaping: aesthetic goals

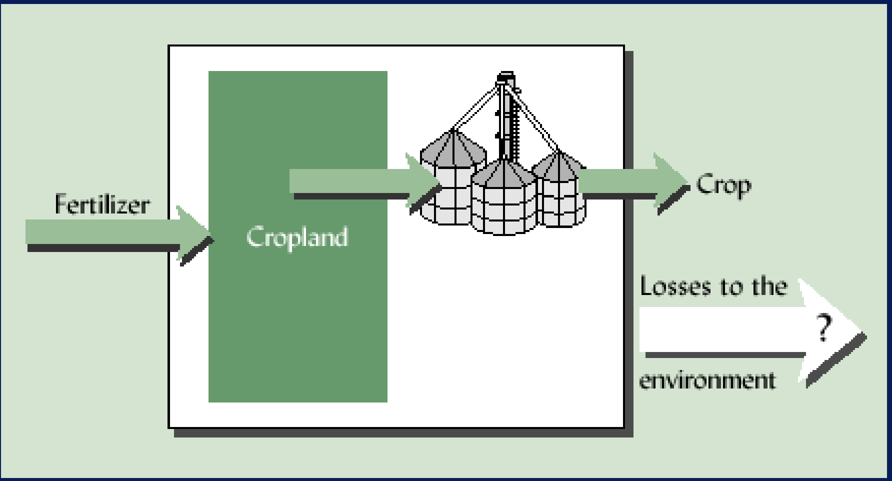
GOALS OF NUTRIENT MANAGEMENT-2

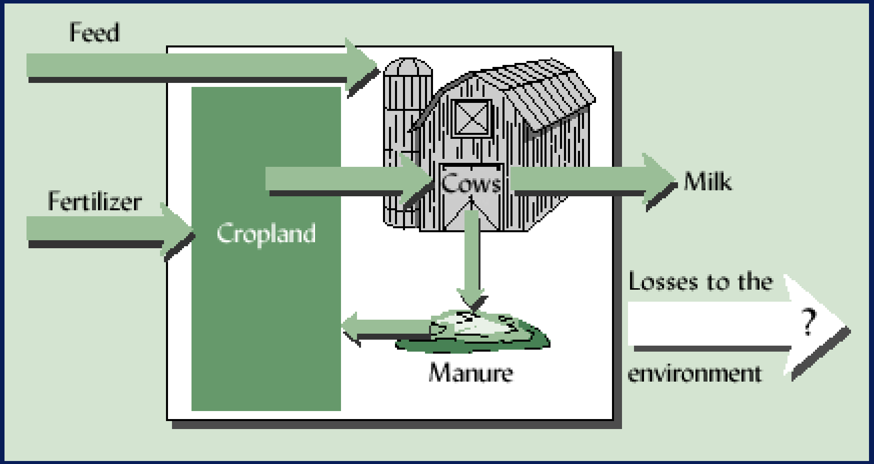
Conservation of natural resources:

Two key concepts:

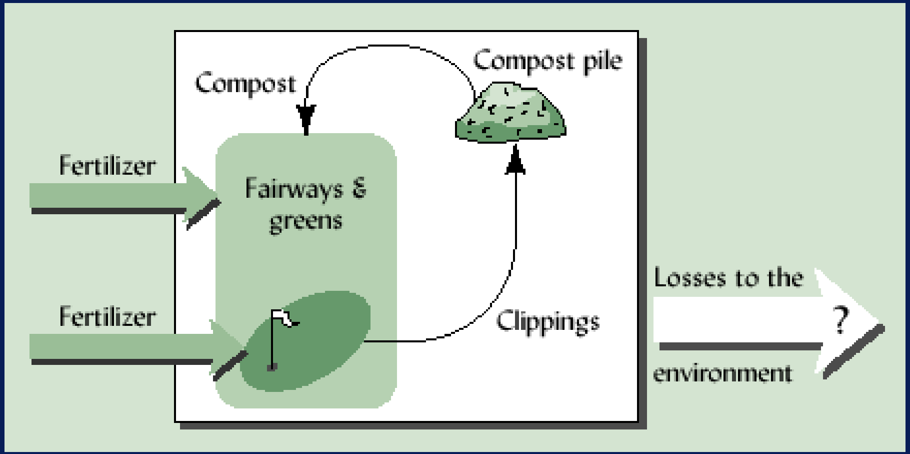
- renewal or reuse of the resources
- nutrient budgeting that reflects a balance between system inputs & outputs
- recycling in the form of returning nutrients to the soil from which they were removed
- "renewable resource" applies best to N; fixed from atmos N by biol & chem processes
- increased use of commercial fertilizers in developing countries may stress natural sources; increasing costs and environmental damage
- note nutrient flowcharts (see Figure 16.1)

GOALS OF NUTRIENT MANAGEMENT-3





Representative conceptual nutrient flowcharts



(Figure 16.1)

GOALS OF NUTRIENT MANAGEMENT-4

Nutrient budgets:

- may need to compute on watershed, regional or national scale
- in most temperate regions there are net positive nutrient balances (more applied than removed)
- many countries have regional nutrient imbalances & concomitant water-pollution problems
- large feedlots & poultry industry are examples of high concentrations of nutrients (wastes)

Soil quality and productivity:

- concept goes beyond providing nutrients for 1 yr
- needs to address long-term nutrient-supplying & -cycling capacity of the soil
- integrated mgmt of phys, chem & biol processes

ENVIRONMENTAL QUALITY - 1

Nutrient management impacts the environment most directly in the area of water quality

Both N and P cause water quality problems through point and nonpoint sources

Nutrient levels reaching surface waters are significantly increased in watersheds with intensive agricultural activity

Major water-quality problems assoc'd with excess N & P:

- growth of most aquatic plants is limited by N &/or P
- in most freshwater bodies, P is most limiting
- in most saltwater bodies, N is most limiting
- excess N & P causes excess plant growth, eutrophication
- results are: low O_2, depletion of SAV (see Table 16.1)

ENVIRONMENTAL QUALITY - 2

Nutrient-management plans:

- designed to control nonpoint source pollution, save nutrient resources and $$$
- may be designed on a watershed and/or an individual farm basis
- current standards are being set as maximum allowable daily loadings (MDLs)
- See Table 16.3 for components of mgmt plan

Best management practices (☐BMPs):

- strategies designed to reduce nutrient loading of surface waters
- types of practices are: (1) buffer strips, (2) cover crops, (3) conservation tillage and (4) forest stand management

ENVIRONMENTAL QUALITY - 3

Riparian buffer strips:

- strips of dense vegetation along surface water body protects water from nutrients
- water velocity is slowed and soil particles settle
- nutrients are sorbed by vegetation & OM
- increased retention time allows for microbial breakdown of pesticides
- must maintain by minimizing equipment intrusion and prevent livestock intrusion
- often a width of 10 m is sufficient
- can use strip for wildlife, recreation, harvest hay

ENVIRONMENTAL QUALITY - 4

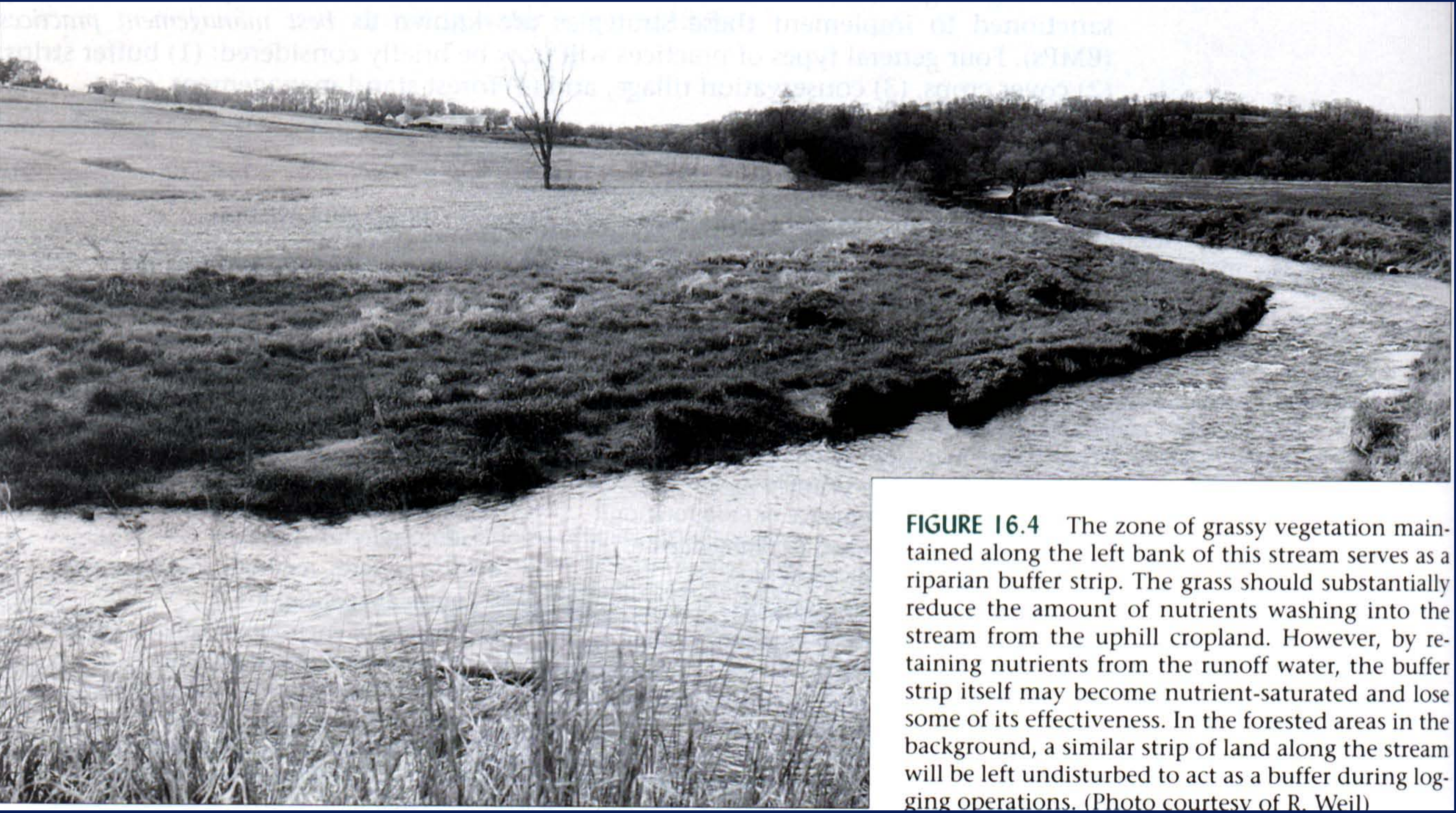


FIGURE 16.4 The zone of grassy vegetation maintained along the left bank of this stream serves as a riparian buffer strip. The grass should substantially reduce the amount of nutrients washing into the stream from the uphill cropland. However, by retaining nutrients from the runoff water, the buffer strip itself may become nutrient-saturated and lose some of its effectiveness. In the forested areas in the background, a similar strip of land along the stream will be left undisturbed to act as a buffer during logging operations. (Photo courtesy of R. Weil)

ENVIRONMENTAL QUALITY - 5

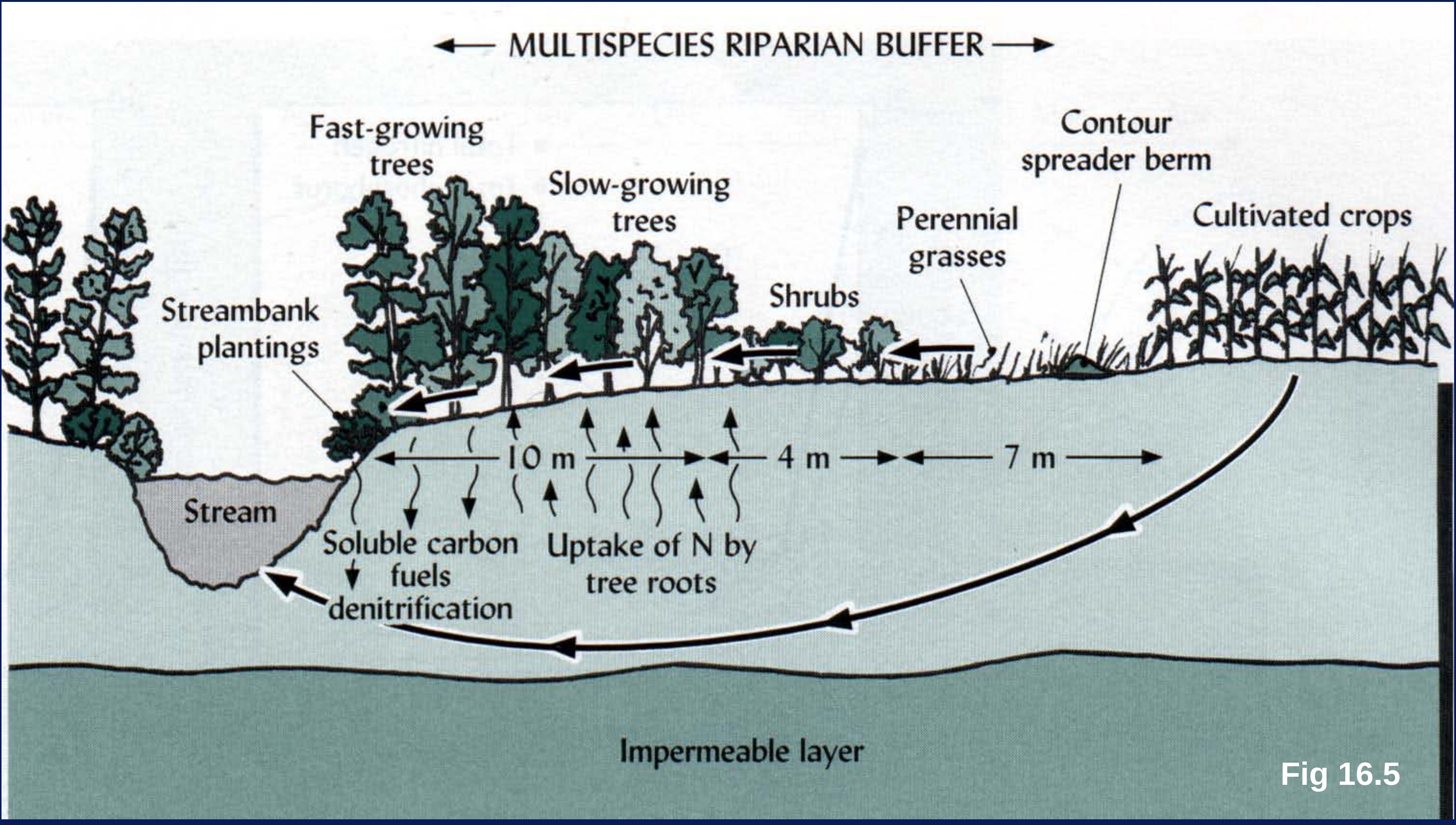
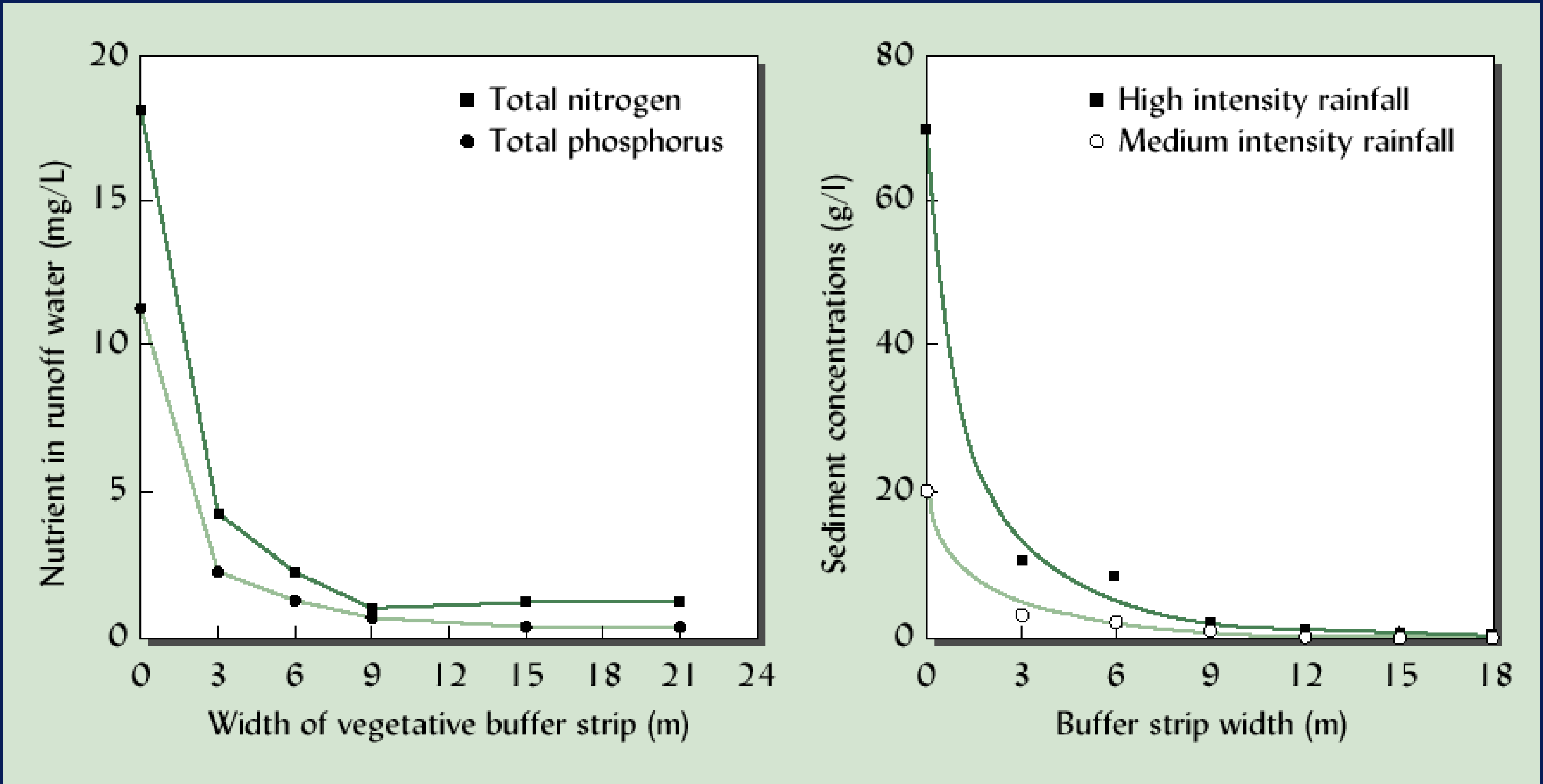


Fig 16.5

ENVIRONMENTAL QUALITY - 6

Removal of nutrients & sediments from runoff by vegetative buffer strips of various widths. (Fig 16.6)



ENVIRONMENTAL QUALITY - 7

Cover crops:

- provides vegetative cover; is killed & left on surface or tilled into soil as green manure
- reduces nutrient losses in runoff by (1) maintaining high infiltration rate & (2) filtering nutrients & sediment from water
- reduces leaching losses by sorbing nutrients and uptaking water
- grasses such as winter annual cereals are best

Conservation tillage:

- reduces runoff & load of nutrients & sediment carried by runoff, similar to buffer strip
- more effective when combined with a cover crop
- leaching losses may be significant due to greater infiltration of water; maybe not in all cases

ENVIRONMENTAL QUALITY - 8

Nutrient losses associated with forest management:

Undisturbed forests lose nutrients primarily by:

1. **Leaching & runoff of dissolved ions & organic cmpds**
2. **Erosion of organic litter & mineral particles**
3. **Volatilization of certain nutrients during fires**

Production practices for wood products production tends to increase losses by all three pathways

Clear-cutting methods produce most soil damage and greatest nutrient losses

Selective cutting is ecologically more sound but may be more expensive; more frequent disturbance

Fertilization of forests is becoming more common; need to take care not to have excessive nutrient losses

NUTRIENT RESOURCES AND CYCLES

Weathering of parent materials: an internal resource:

- weathering of minerals may release significant quantities of nutrients
- usually sufficient for forests; generally not for agricultural systems, esp. for N
- mineralization from OM impt in short-term

Nutrient economy of forests:

- OM mineralization is main source of nutrients
- rates of uptake closely matches release by miner'ln
- most OM is from fine roots & mycorrhizal hypha
- recycling/storage within plants
- trees enrich surface soil by leaf fall
- deep roots bring up nutrients from lower profile

NUTRIENT RESOURCES AND CYCLES

Some effects of fire:

- hot-burning forest wildfires volatilize N, S, some P
- ash contains K, Ca, Mg & P which are increased in short-term availability; also increased losses
- fire retardants are mostly fertilizer-type materials; may assist in regrowth; may result in increased losses
- could be phytotoxicity of B for several years

Rangeland nutrient recycling:

- less volatilization losses than in forest fires
- nutrient release generally stimulates biomass production
- grazing by large mammals can also stimulate biomass production

NUTRIENT RESOURCES AND CYCLES

Leguminous cover crops to supply nitrogen:

- plant legume as cover crop, kill or plow into soil in spring just as main crop is sown/planted
- may replace all or part of N from fertilizer
- increasingly used in sustainable agric systems & organic farming (due in part to P restrictions)

Crop rotations:

- advantageous due to
  - weed, disease & insect pest reduction
  - fertility effect of different rooting patterns
  - different residue types & nutr requirements
  - synergistic effects

RECYCLING NUTRIENTS THROUGH ANIMAL MANURES

- Huge quantities of manure are available each year for possible return to land

- Problem today is concentration of manures from feedlots

Cattle feedlots:

- a 100,000-head beef feedlot produces 200,000 Mg of manure annually
- would need 17,000 ha of corn silage land
- need to transport away from feedlot area to use

Poultry manure:

- concentrated production, must transport feed to poultry "factories"
- have large quantities of manure for disposal

RECYCLING NUTRIENTS THROUGH ANIMAL MANURES

Nutrient composition of animal manures:

- large proportions of consumed nutrients are excreted
- both liquid & solids are valuable
- handling and application is difficult; with significant transport becomes more expensive
- dry wt basis: 2-5% N; 0.5-2% P; 1-3% K

Storage, treatment & management of animal manures:

Confinement systems:

- packed in piles
- stored in aerated ponds
- stored in anaerobic lagoons

RECYCLING NUTRIENTS THROUGH ANIMAL MANURES

Storage, treatment & management of animal manures:

Loss of nutrients (Table 16.11):

- volatilization; washed away during rains; seepage from unlined ponds

Heat-dry and pelletize:

- dry manure and then compress into pellets
- uses considerable energy and capital investment but product is in demand

Commercial composting:

- is becoming a more popular method of disposal
- produces easy to handle, slow-release fertilizer
- requires considerable management and labor

RECYCLING NUTRIENTS THROUGH ANIMAL MANURES

Storage, treatment & management of animal manures:

Anaerobic digestion with biogas production:

- liquid slurry produces biogas comprised of ~80% CH_4 & 20% CO_2
- now some large-scale operations
- generate electricity which is sold to utility companies
- process solids as described above

INDUSTRIAL AND MUNICIPAL BY-PRODUCTS

Garbage:

- 50-60% of municipal solid waste (MSW) consists of decomposable materials
- remove glass, metals, etc. and compost remaining material
- has low nutrient content; cost to transport is high
- cost is becoming more competitive with present disposal methods

Food-processing wastes:

- land application is conducted in some locations
- more for pollution abatement than crop prod’n
- plant-processing schedules may not be suitable for optimum crop production

INDUSTRIAL AND MUNICIPAL BY-PRODUCTS

Wood wastes:

- sawdust, wood chips, shredded bark is mostly used as mulches
- high in lignin & related products, very high C/N ratio, so decomposes slowly

Recycling by composting:

- combine domestic, garden, community, some industrial wastes and produce compost
- yard trimmings, food scraps, supermarket wastes, paper combined with sawdust, manure, some industrial wastes (e.g., coal ashes)
- increasingly popular method

INDUSTRIAL AND MUNICIPAL BY-PRODUCTS

Wastewater treatment by-products:

- sewage sludge or biosolids
- effluent water where N & P reduction is needed

Sewage effluent:

- apply to land for crop irrigation, especially forests
- suitable land is not always conveniently located
- provides nutrients, organic compounds are degraded by microbes
- organic & inorganic constituents are sorbed by soil colloids
- percolation of purified water recharges ground H_2O

INDUSTRIAL AND MUNICIPAL BY-PRODUCTS

Biosolids (sewage sludge):

- can be applied to land for various purposes
- can be applied to cropland if it meets standards
- liquid slurry contains 80-90% H_2O
- dried cake contains 40-70% H_2O
- composition of nutrients & trace ele's is variable
- levels of N, P & K are low (4, 2, 0.4% respectively)

Integrated recycling of wastes:

- relatively new concept to USA
- practiced extensively in heavily populated countries, especially China & Japan
- note complex use pattern in Figure 16.23 ???
- will be practiced to a greater extent in USA

PRACTICAL UTILIZATION OF ORGANIC NUTRIENT SOURCES

Principles for application of organic materials to soils:

1) rate of application is governed by avail N & P
2) most N is slowly available to plants (Table 16.11)
3) for fields with annual treatments, appl'n rate will become progressively smaller
4) nutrient & moisture content of organic materials varies considerably & must be carefully ck'd
5) cost of transportation may lead to over appl'n of organic materials to soils close to sources

Special uses:

- denuded soil resulting from erosion
- from land-leveling for irrigation
- reclamation from mining operations

INORGANIC COMMERCIAL FERTILIZERS

Regional use of fertilizers:

- specific usage within a region denotes whether or not fertilizers are contributing to soil qual enhancement or environ degradation
- in Europe & East Asia, fertilizer application rates are 3X world average
- in sub-Saharan Africa, soils are being mined of nutrients - fertl'n rate is 10% of world avg

Origin and processing of inorganic fertilizers:

Potassium - subsurface salt beds: KCl & K_2SO_4

Phosphorus - phosphate rock deposits: treated with H_2SO_4, H_3PO_4 or HNO_3

Nitrogen - N_2 from atmos is fixed with H_2 to form NH_3; requires tremendous amts of energy

Mixed fertilizers - $NH_3H_2PO_4$, $(NH_3)_2HPO_4$, KNO_3

INORGANIC COMMERCIAL FERTILIZERS

Properties and use of inorganic fertilizers:

- primary fertilizer elements: N, P, K
- other manufactured forms: S, Mg, micronutrients
- many possible combinations, compounds
- must consider chemical compatibilities

Physical forms of marketed fertilizer:

- bulk form: unbagged, dry solids - custom blended
- liquid or fluid forms: >50% single-nutrient carriers
- paper or plastic bags: 10% of fertilizer in US

Fertilizer grade:

- 10-5-10 of N-P-K: % total N; % available phosphoric acid (P_2O_5); soluble potash (K_2O)
- oxide units are relics of reporting element conc's by geologists; are written into state laws

INORGANIC COMMERCIAL FERTILIZERS

Fate of fertilizer nutrients:

- nutrients added from organic & inorganic sources are incorporated into complex soil nutrient cycles
- little (10-60%) of fertilizer nutrient is taken up by plant during year of fertilizer application
- much N is utilized by microorganisms
- most moves into various soil pools

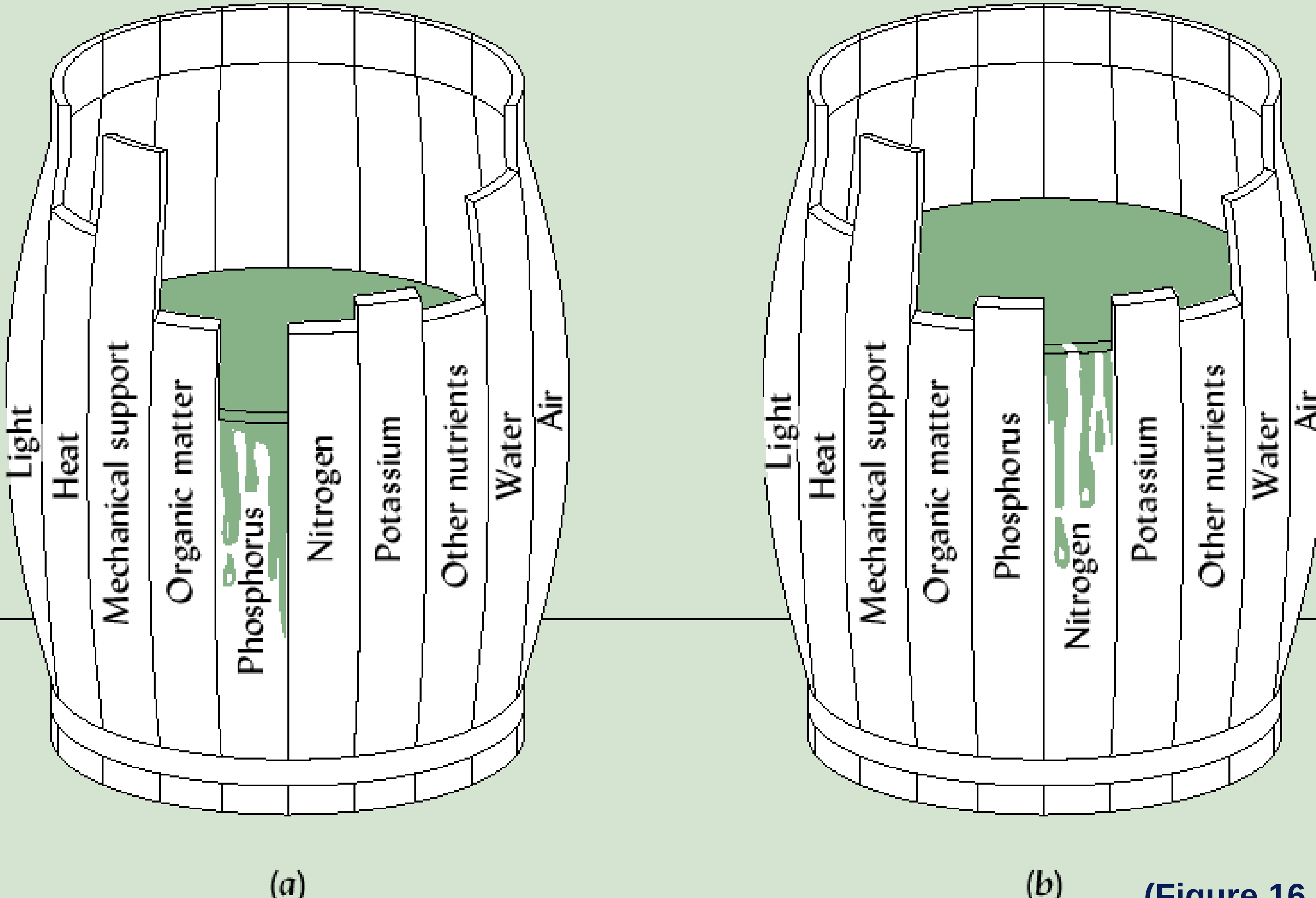
The concept of the limiting factor:

- German chemist, Justus von Liebig:

"plant production can be no greater than the level allowed by the growth factor present in the lowest amount relative to the optimum amount for that factor"

- effect is same: 1g B or 1kg N

CONCEPT OF THE LIMITING FACTOR



(Figure 16.26)

FERTILIZER APPLICATION METHODS

Broadcasting:

- fertilizer spread evenly over entire area; good for close-growing crops, lawns
- may be applied to soil, plowed in prior to planting
- elements may bind with soil outside of root zone
- may add fertilizer to irrigation water (fertigation)

Localized placement:

1) minimized contact with soil minerals that would cause fixation reactions
2) soil solution concentrations are very high near fertilizer, more rapid uptake

FERTILIZER APPLICATION METHODS

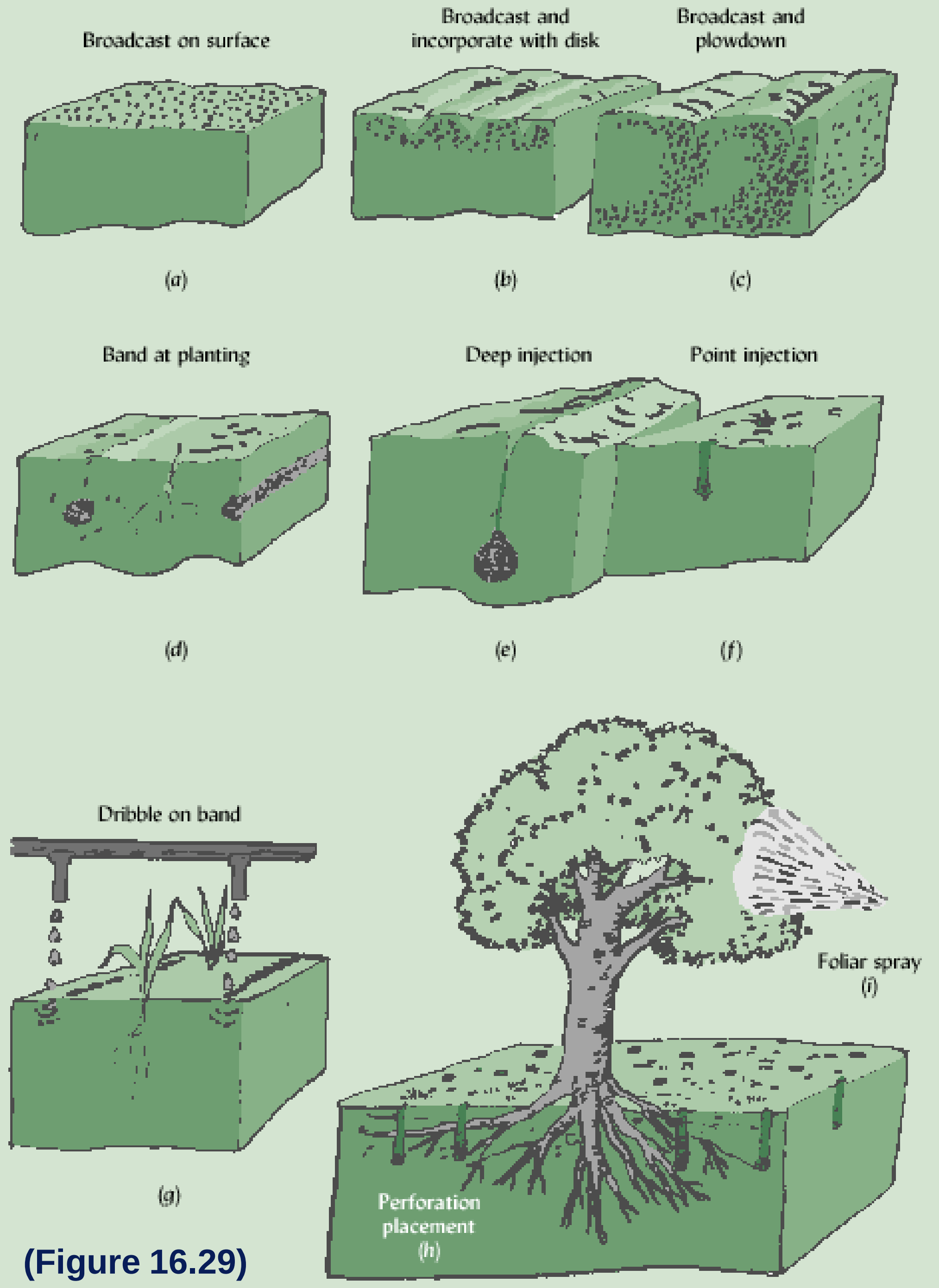
Localized placement, con’t:

- Starter application: very effective for young seedlings
- Liquid fertilizers: place with knife injectors
- Dribble application: use small stream along plants
- Point injection: liquid fertilizer applied to each plant
- Drip irrigation: very efficient method
- Perforation method for trees: drill holes around tree, add fertilizer, fill hole

Foliar application:

- used in special circumstances
- limited amounts absorbed at any one time (appl’n)
- must take care not to cause salt damage
- use for most rapid response to problem

FERTILIZER PLACEMENT METHODS



(Figure 16.29)

TIMING OF FERTILIZER APPLICATION

Availability when the plants need it:

- for mobile nutrients (N, K) apply as close as possible to rapid growth phase
- multiple applications, varies with crop

Environmentally sensitive periods:

- most leaching occurs in winter & early spring in temperate climates - prior to spring growth
- can have leaching of “left-over” after growth stops
- use two or more split appl’ns in high rainfall areas

Physiologically appropriate timing:

- excess N in summer may stress cool-season grass
- extra K in fall improves winter hardiness
- adding sufficient P to rooting zone when planting trees is very beneficial

DIAGNOSTIC TOOLS AND METHODS

Plant symptoms and field observations:

- careful observation of plant condition & character
- may be able to ID one or a few elements as deficient

Plant tissue analysis:

- **Nutrient concentrations:**
  - conc'n in tissue is related to plant growth or yield
  - sufficiency range is where tissue conc'ns are adequate for optimal growth
  - critical range is where less nutrient will decrease growth but there may be no visible defic symptoms
- **Tissue analysis:**
  - must know when (growth stage) and what plant part to sample
  - very useful but needs skill in interpretation

PLANT GROWTH VS CONCENTRATION IN TISSUE

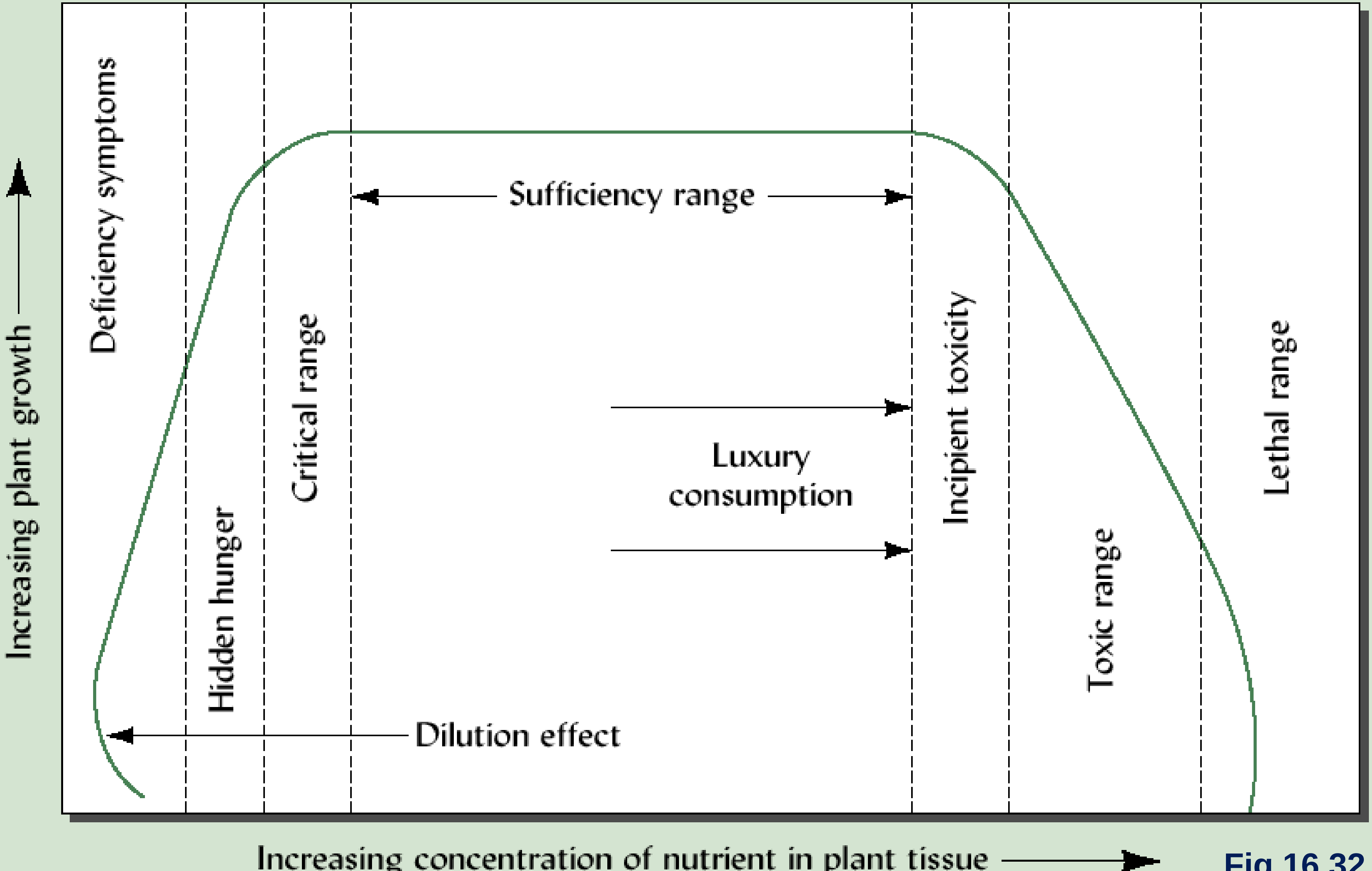


Fig 16.32

SOIL ANALYSIS

Sampling the soil:

Composite sample: use soil probe to take cores at several places and composite for sample

Depth to sample: generally the plowing depth, 15-20 cm

Time of year: avail of different elements will vary through the year; be consistent with sampling time

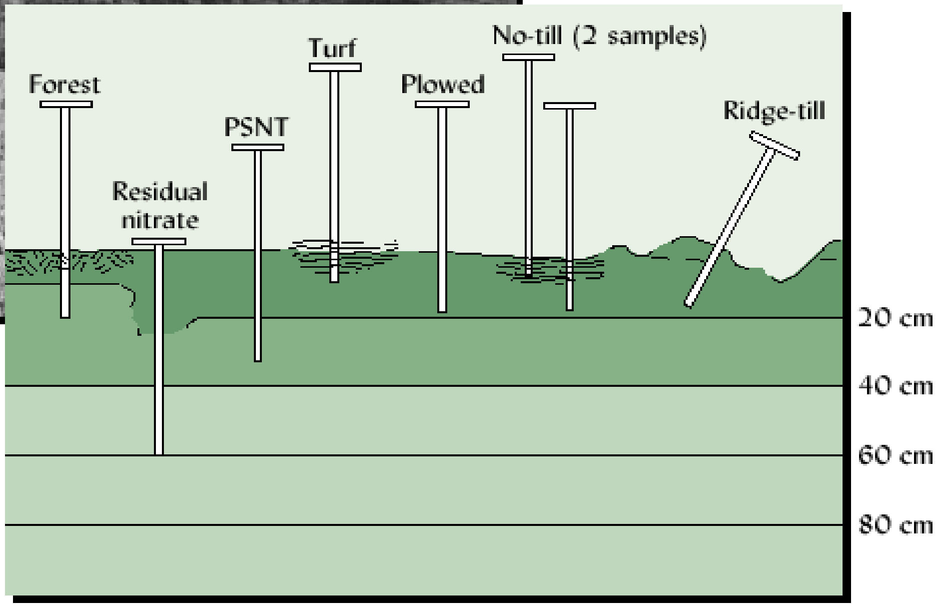
Chemical analysis of the sample:

- **special extractants are used to est avail nutrients**
- **most common & reliable tests: pH, K, P, Mg**

Merits of soil testing:

- **very useful, but there are limitations**
- **most dependable when correlated with field fertilizer experiments**

TAKING SOIL SAMPLE IN FIELD



(Figure 16.35)

RELATIONSHIP BETWEEN SOIL TEST RESULTS AND EXTRA YIELD FROM FERTILIZATION

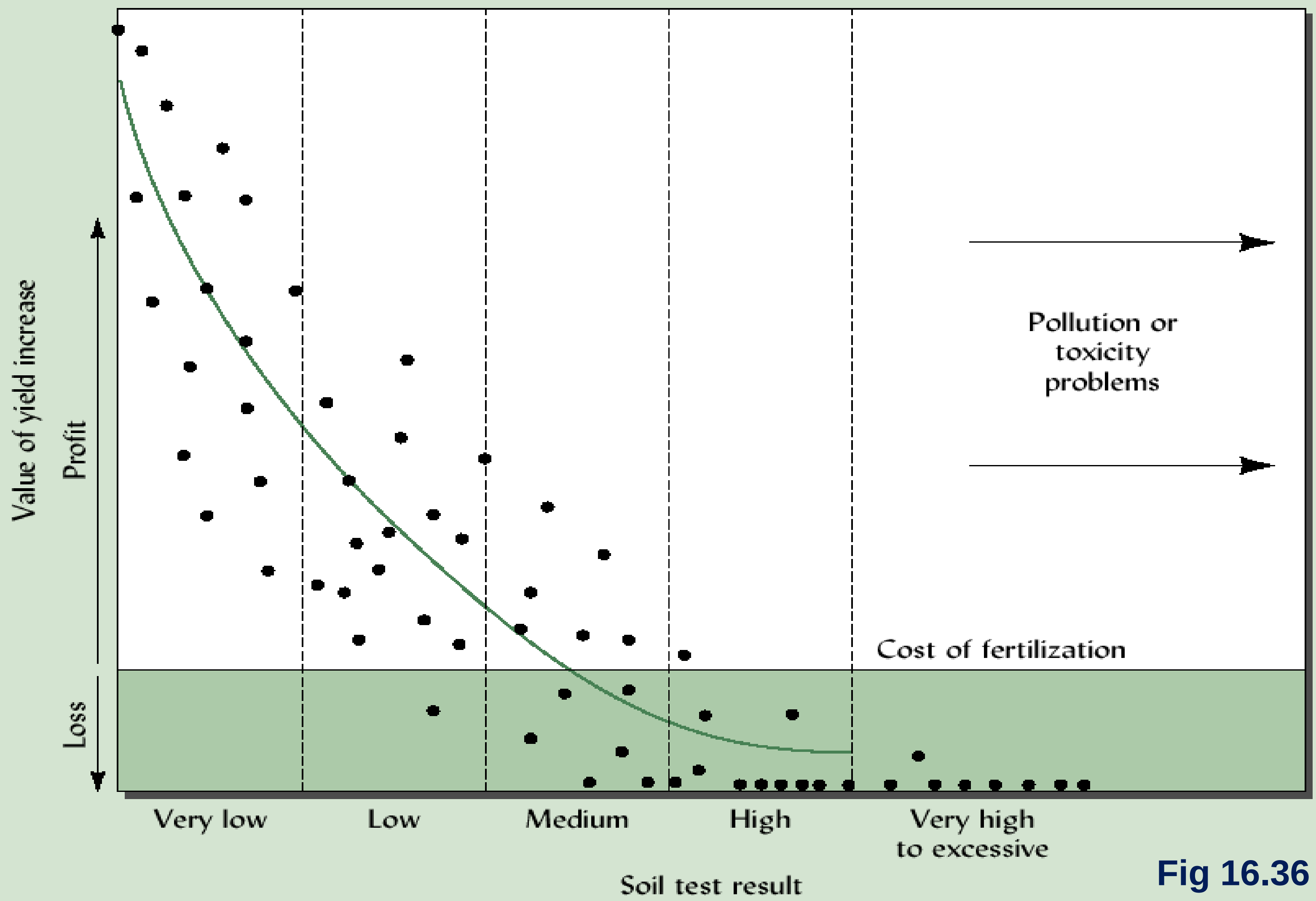


Fig 16.36

SITE-SPECIFIC NUTRIENT MANAGEMENT

- Use GPS when taking soil or tissue samples and use to guide fertilizer applications
- Can utilize numerous soil properties (pH, clay, etc., along with fertilizer recommendations
- Apply nutrients with computer controlled spreader
- Yield results are also entered into database for integrated approach to plant production

SITE-INDEX APPROACH TO PHOSPHORUS MANAGEMENT

P is one of two major water pollutants

Agriculture is the major nonpoint source of P water poll'n

Overenrichment of soils:

- many soils have excessive P due to years of over application, based on past recommendations
- concentration of livestock and heavy use of manures in nearby soils

Transport of P from land to water:

- attached to eroded soil particles
- dissolved in water running off surface (no till, forest)
- dissolved or attached to colloidal particles in percolating waters

SITE-INDEX APPROACH TO PHOSPHORUS MANAGEMENT

Phosphorus soil test level as indicator of potential losses:

- phosphorus in eroded sediment
- phosphorus in runoff water
- phosphorus in drainage water

Site characteristics influencing transport of phosphorus:

- soil erodibility, presence of buffer strips, soil slope, use of conservation tillage

Phosphorus site index:

- most P reaching water bodies comes from small portion of watershed
- assign index of pollution risk to different areas, evaluate and focus efforts on those with greatest pollution potential

BROADER ASPECTS OF FERTILIZER PRACTICE

Initial focus is on N in most soil fertility plans due to plant needs and environmental quality concerns

N recommendations are made on the basis of field experiments with specific crops

Applications of other nutrients are made to balance N supply, also using soil test results

N credits:

- need to account for N remaining in soil, added by crop residues, climate rate of leaching, etc.

Profitability:

- need to make highest profit; not highest yield

Response curves:

- use math models for diff soil/plant systems

FERTILIZER ADDITION, CROP YIELD INCREASE, FERTILIZER COSTS & PROFIT

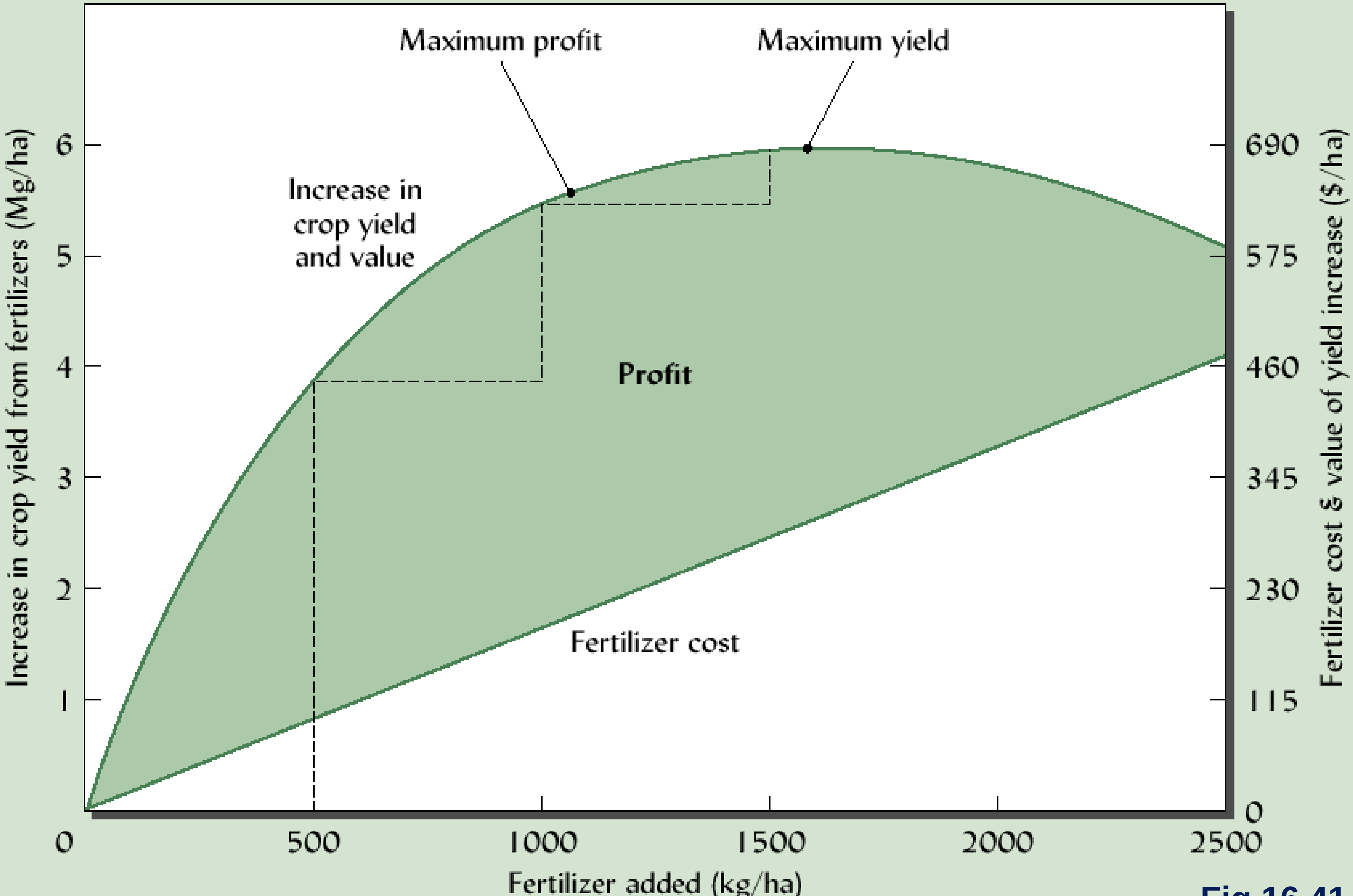


Fig 16.41

INFLUENCE OF RATE OF NITROGEN FERTILIZATION ON CROP YIELD, N IN HARVEST, EXCESS SOIL N

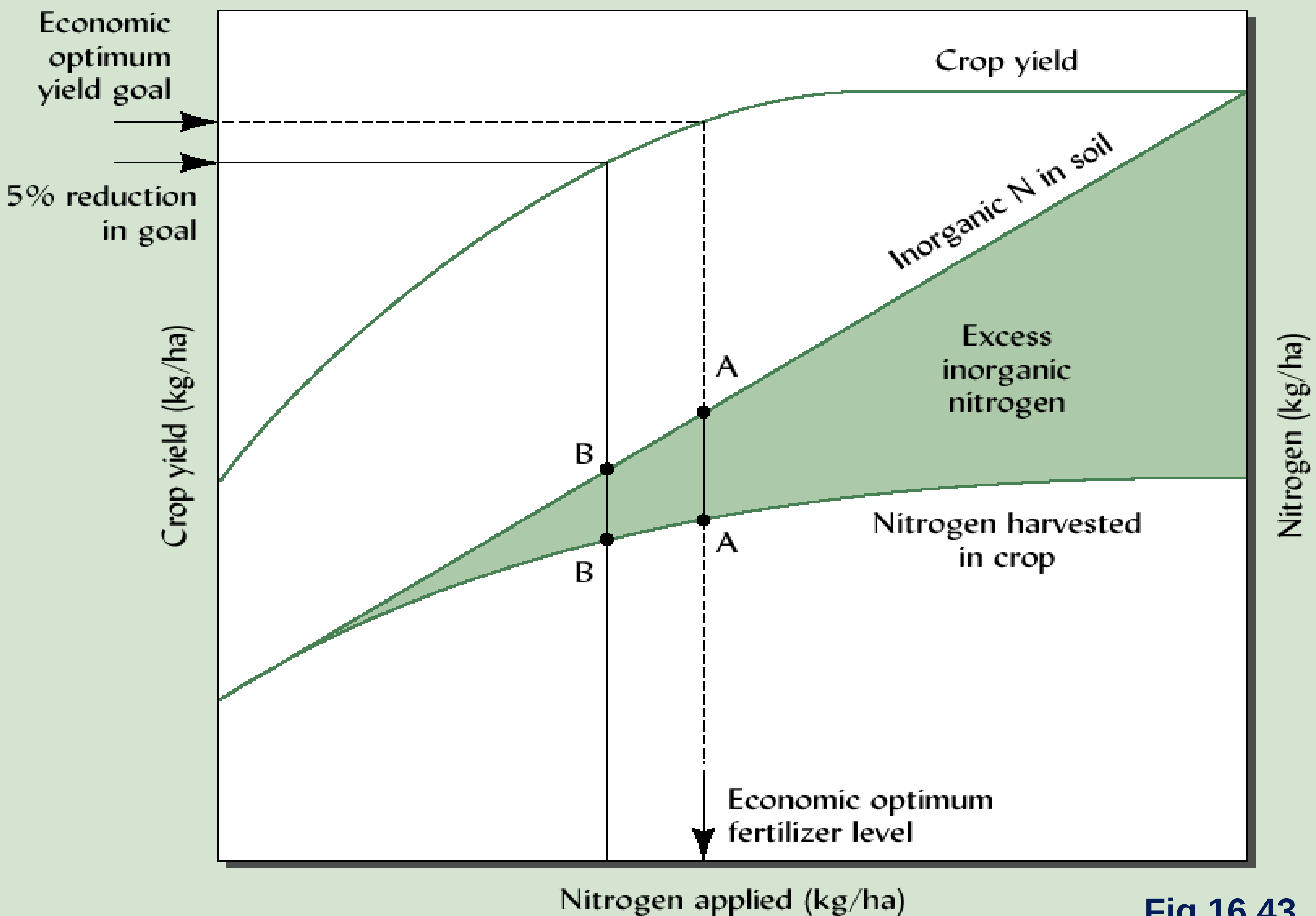


Fig 16.43