LECTURE 6: ESTIMATION OF NUTRIENT REQUIREMENT

TOPICS OF DISCUSSION

1. Estimation of Fertilizer Requirement
   A. A Simple Approach
      - Plant nutrient
      - Expected yield
   B. Yield Response
2. Best Management Practices

1. A SIMPLE APPROACH

- **Nutrient requirement depends on**
  1. Targeted yield and soil nutrient supply
  2. Type of fertilizer and recovery
  3. Timing (which is dependent on the maturity of variety)
- **To estimate fertilizer requirements we need to know**
  1. Target yield
  2. Crop yield with no fertilizer
  3. Fertilizer recovery

- **Example**
  1. Target yield: 4.5 t/ha
  2. Yield without fertilizer: 1.5 t/ha
  3. Yield from the fertilizer: 4.5 – 1.5 = 3 t/ha
  4. Approximate fertilizer needed per tonne of crop

     N = 15 - 20 kg N/ton yield

     P = 2.5 – 3 kg P/ton yield

     K = 15 – 20 kg K/ton yield

- Thus to get additional yield of 3 tonnes grain per/ha the crop require an additional
  - 3 (15 - 20) = 45 – 60 kg N/ha
  - 3 (2.5 – 3.0) = 7.5 – 9 kg P/ha
  - 3 (15 – 20) = 45 – 60 kg K/ha
- N recovery is typically of the order of 50% thus
  - (45-60 kg N per ha)/0.5 → 90-120 kg N per ha
- The use of slow release of urea (super granules) by deep placement → increases the recovery of N and thus the quantity of fertilizer can be reduced.

- If 1/3 N as basal , 1/3 at mid tillering and 1/3 at panicle initiation, the recovery of N is of the order of
  - 35% basal application
  - 45% at tillering
  - 65% at panicle initiation
- Therefore 1/3 x 30% + 1/3 x 45% + 1/3 x 65% = 48% total recovery.
- If there is no basal, 1/3 delayed, 2/3 at PI, then the recovery in the order of 40% and 60% of applied N respectively.
- Therefore 1/3 x 40% + 2/3 x 60% = 53% total recovery.

Nutrient content of Rice

Plant Parts	kg/ ton grain					
	N	**P_2O_5**	**K_2O**	**MgO**	**CaO**	**S**
Straw	7.6	1.1	28.4	2.3	3.8	0.34
Grain	16.6	6.0	3.2	1.7	0.14	0.6
Total	**22.2**	**7.1**	**31.6**	**4.0**	**3.94**	**0.94**

Plant Parts	g/ ton grain					kg/ ton grain	
	Fe	**Mn**	**Zn**	**Cu**	**B**	**Si**	**O**
Straw	150	310	20	2	16	41.9	5.5
Grain	200	60	20	25	16	9.8	4.2
Total	**350**	**370**	**40**	**27**	**32**	**51.7**	**9.7**

1. Species and Nitrogen Content

N & Productivity	Rice		Maize	Cassava	Sweet Potato
	Sawah	Gogo			
N (kg/ton yield)	22.2	22.2	23	4.9	4.7
Yield (ton/ha)	8	4	8	20	15
Total (kg N/ha)	**177.6**	**88.8**	**184**	**98**	**70.5**
Urea (kg/ha)	394.7	197.3	408.9	217.8	156.7
Urea (kg/ha)*	355.2	177.6	368.0	196.0	141.0

*10% is taken from the soil N

A. Simple Approach

1. How much is a particular nutrient (e.g. N) required to produce a unit of yield
2. What is the target of yield
3. What is the nutrient content of fertilizer choice

1.	N requirement (kg/ton yield)	U
2.	Targeted productivity (ton/ha)	P
4.	N content of Urea	μ

For instance N (Nitrogen)

Total N Requirement ; N = U * P (kg/ha)

Total Urea = N/μ

Example:

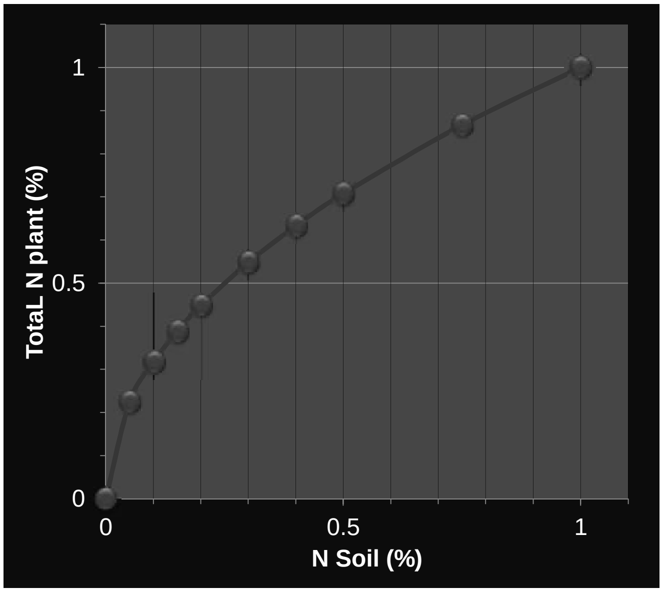
- U = 22.2 kg N/ton yield
- P = 6 ton/ha
- N = 22.2*6 = 133.2 kg N/ha
- N content of Urea = 0.45
- Urea = (133.2 kg/ha)/0.45 = 296 kg/ha

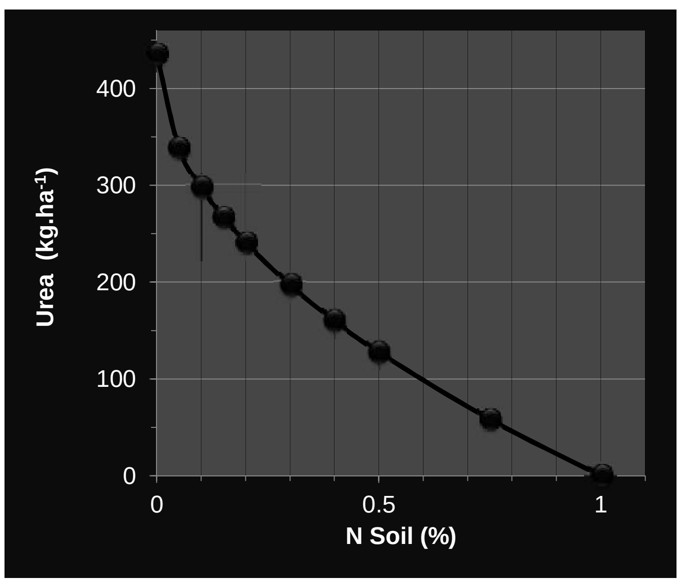
1.	N requirement (K/ton yield)	U
2.	Targeted productivity (ton/ha)	P
3.	Total N Required (kg/ha)	A = U*P
4.	N content of Urea	μ
5.	N uptake efficiency	ε
6.	Soil N (%)	α
7.	Soil N (kg/ha)	Ns

$$Urea = U*P*[1-(\alpha/100)^{0.5}]/(\mu*\varepsilon)$$

NITROGEN REQUIREMENT FOR IRRIGATED RICE				
N requirement (kg/ton yield)			U	22.2
Targeted productivity (ton/ha)			P	6
Total N Required (kg/ha)			A = U*P	133.2
N content of Urea			μ	0.45
N uptake efficiency			ε	0.68
N uptake fraction			μ ε	0.306
Correction			λ	0.5
Soil	Soil N	N Fraction from Soil =	Fert N	
(t/ha)	(%)	NSF = (Soil N/100)$^{\lambda}$	NR = (1-NSF)*A	Urea
2.2	0.00	0.00	133.2	435
2.2	0.05	0.22	103.4	338
2.2	0.10	0.32	91.1	298
2.2	0.20	0.45	73.6	241
2.2	0.30	0.55	60.2	197
2.2	0.40	0.63	49.0	160
2.2	0.50	0.71	39.0	127
2.2	0.75	0.87	17.8	58
2.2	1.00	1.00	0.0	0

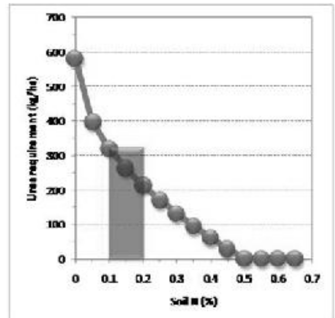
NR = N required *(kg/ha)


TotaL N plant (%)
1
0.5
0
0
0.5
1
N Soil (%)


Urea (kg.ha-1)
400
300
200
100
0
0
0.5
1
N Soil (%)

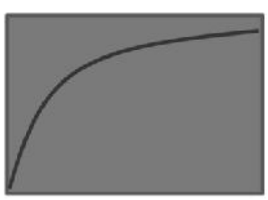
Nitrogen Requirement for Irrigated Rice

Kebutuhan hara/ton hasil (U, kg/ton)			U	22.2
Targeted produktivity (P, t/ha)			P	8
Total N Required (A, kg/ha)			A	177.6
N content of Urea (m, ratio)			m	0.45
N uptake efficiency (e, ratio)			e	0.68
			me	0.306
Correction (l , ratio)			l	0.5
Soil	N(%)	N*	Fert N	
(t/ha)		Soil	Req.	Urea
2.2	0.00	0.00	177.6	580
2.2	0.05	0.32	121.4	397
2.2	0.10	0.45	98.2	321
2.2	0.15	0.55	80.3	262
2.2	0.20	0.63	65.3	213
2.2	0.25	0.71	52.0	170
2.2	0.30	0.77	40.0	131
2.2	0.35	0.84	29.0	95
2.2	0.40	0.89	18.7	61
2.2	0.45	0.95	9.1	30
2.2	0.50	1.00	0.0	0
2.2	0.55	1.00	0.0	0
2.2	0.60	1.00	0.0	0
2.2	0.65	1.00	0.0	0



B. Uptake Approach

1. MICHAELIS-MENTEN MODEL



$$V = \frac{V\max Cs}{Km + Cs}$$

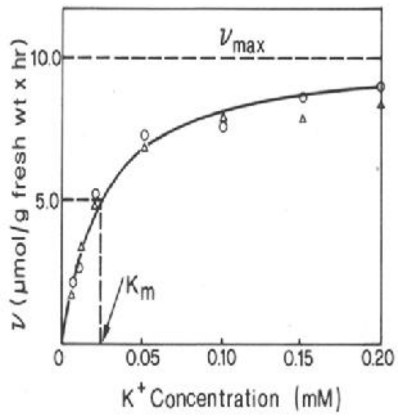
$$N = \frac{N_{Max} N_S}{K_N + N_S}$$

- N = serapan unsur hara (nutrisi, mis. N)
- N_{Max} = Serapan maximum
- N_S = tingkap penyediaan nutrisi
- K_N = konstanta

Kecepatan reaksi enzimatis dan merupakan fungsi dari

- ***Vmax*** *: kapasitas maximum karier yaitu tingkat transport maximum saat semua tempat karier dijenuhi*
- ***Km*** *: Konstanta Michealis-Menten yang sama dengan konsentrasi substrat yang menghasilkan setengah dari tingkat transport ion maksimum*

Gambar. Tingkat serapan K^+ (V) sebagi fungsi dari konsentrasi eksternal dari KCl (o) atau K_2SO_4 (•); Km = 0.023 mM (dari Epstein, 1972)



$$V = \frac{V\max Cs}{Km + Cs}$$

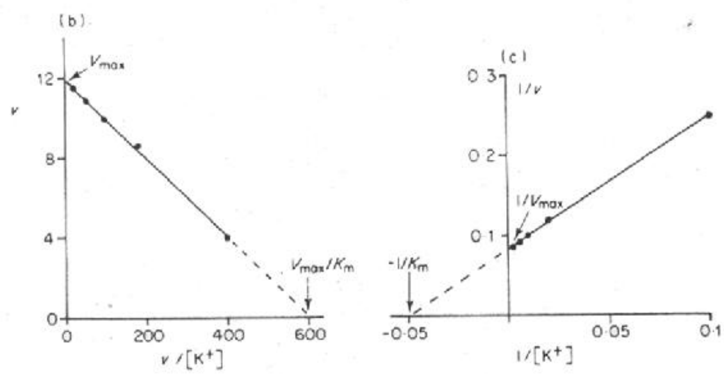


FIG. 3.13. Absorption isotherm for potassium ions (a) and two plots to obtain linearity: (b) Hofstee plot and (c) Lineweaver-Burke plot. $V_{max} = 12$ μmol g^{-1} FW h^{-1}; $K_m = 20$ μM. Hypothetical data.

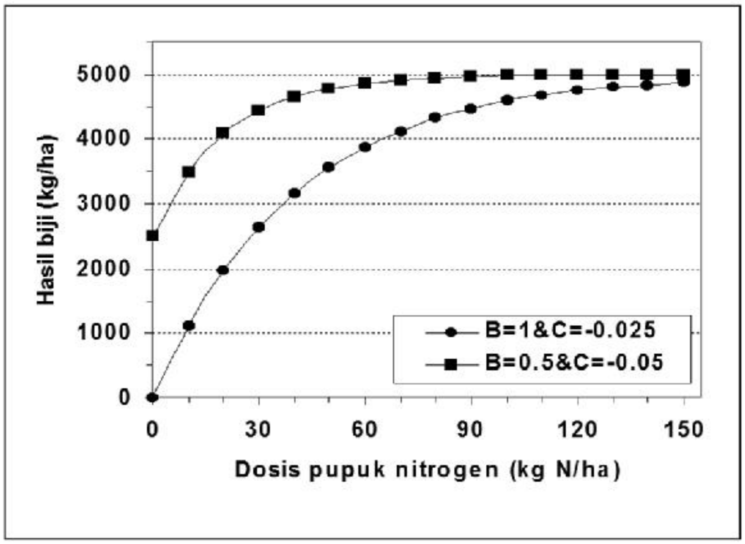
Hasil analisis serapan dengan model Michaelis-Menten

2. MITCHERLICH MODEL

Y = A(1-B.EXP(-CX)) (1)

- Y = hasil/biomassa total tanaman atau serapan unsur hara (kg/ha)
- A = hasil atau serapan maksimum (kg/ha) dengan penyediaan unsur hara yang tidak terbatas
- X = jumlah unsur hara yang diberikan (kg/ha) yang dapat berupa N, P, K dll.
- B & C = konstanta

- Parameter B menggambarkan tanggapan maksimum tanaman pada unsur hara sebagai proporsi dari hasil maksimum yang diperoleh dengan
- $B = (A-Y_0)/A$
- dimana Y_0 = hasil pada X = 0



APPLICATION

Y = A(1-B.EXP(-CX)) (1)

- **Simplify the above equation to be**

  Y/A = (1-B.EXP(-CX)) (1a)

  1-Y/A = B.EXP(-CX)) (1b)

- **Analyze eq. (1b) with an exponential model**

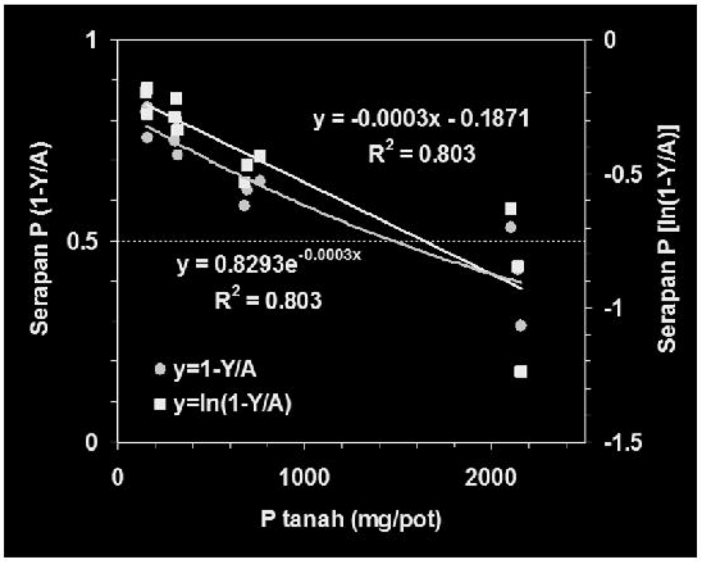
OR

- **Modify eq. (1b) to a linear form as follows**

  ln(1-Y/A) = lnB -CX (1c)

- **Analyze eq. (1c) with a linear model (y = a + bx)**

  where y = ln(1-Y/A), a = lnB, b = C, and x = X



Exponential : B = 0.8293 & C = -0.0003

Linier : ln B = -0.1871 atau B = 0.829361; C = -0.0003

Calculation Procedure

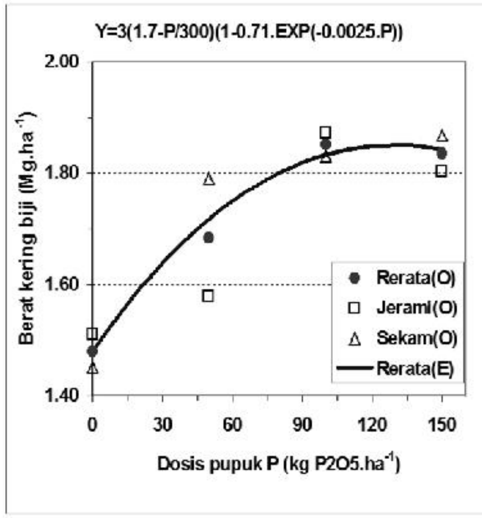
- **Persamaan diatas dapat dimodifikasi untuk melibatkan pengaruh negatif dari unsur hara seperti N atau salah satu unsur lain yang belum dipertimbangkan pada persamaan diatas seperti berikut**

Y = A(~-N/)(1-B.EXP(-CN)) (2)

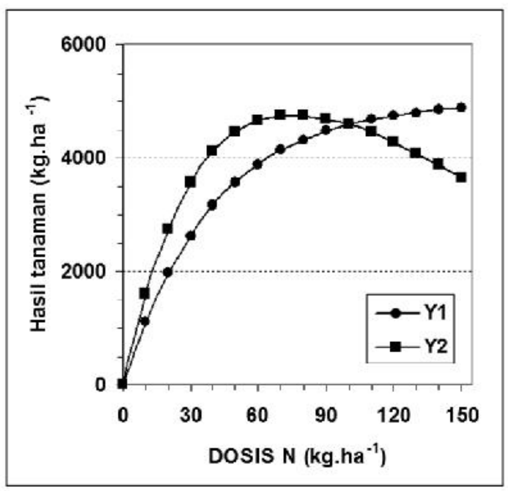
Y = A(~-N/)(1-B.EXP(-CNPK)) (3)

dimana ~ dan adalah konstanta. Harga parameter ~ ñ1, dan adalah dosis unsur hara yang mengakibatkan pengaruh negatif

Pers (3) cukup baik digunakan untuk analisis hasil penelitian pengaruh pupuk P pada tanaman kedelai dengan A (potensi produksi kedelai) = 3 t/ha, B = 0.71, ~ = 1,7, $_{P}$ = 300 kg/ha & C = -0,0025



Tanggapan tanaman pada N tanpa dan dengan pengaruh negatif dari N yang tinggi dengan pers. (3) ditunjukkan pada Gambar 4.5 (A=5000 kg/ha, ~ = 1,5, $_{N}$ = 200, C = -0,00001, P = 50 kg/ha & K = 50 kg/ha)

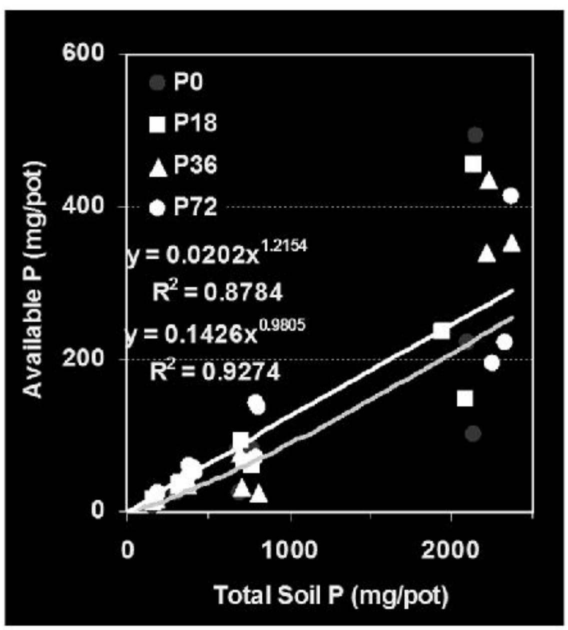


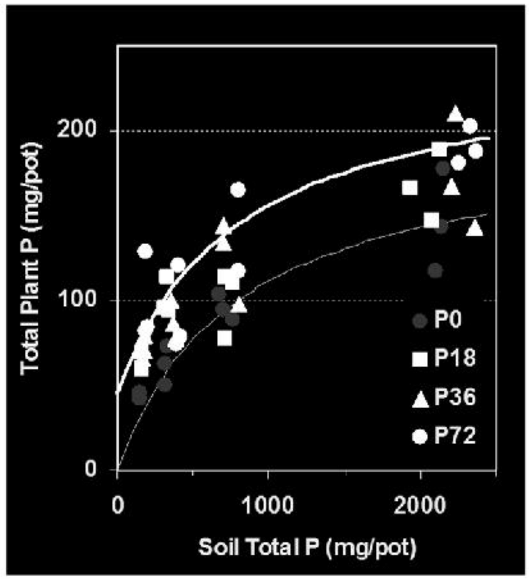
3. OTHER APPROACH

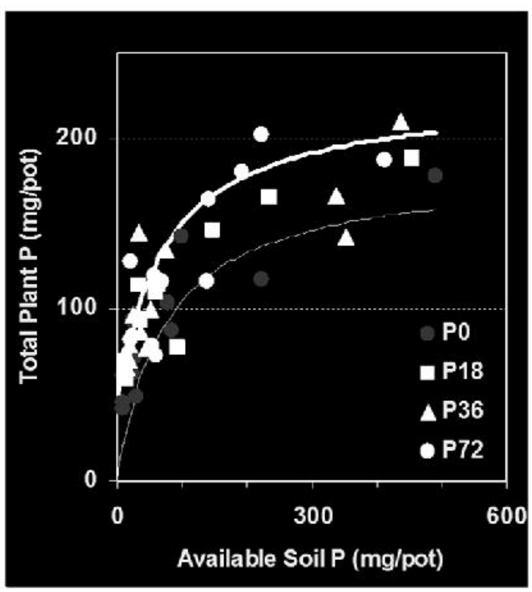
$$S = \frac{U_T}{\alpha + \beta U_T}$$

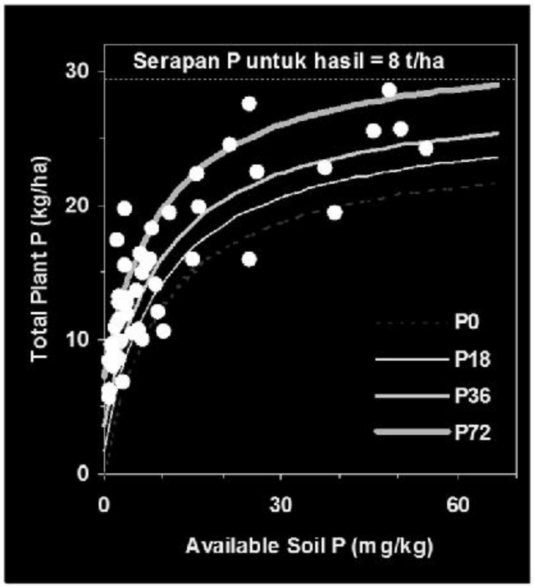
$$S = \frac{U_T}{\alpha + \beta U_T} + k\,U_P$$

- S = Serapan unsur hara (mis. P)
- U = unsur hara dalam tanah (U_T) atau pupuk (U_P)
- a, b & k = konstanta




Total Plant P (mg/pot)
200
100
0
1000
2000
Soil Total P (mg/pot)
P0
P18
P36
P72


Total Plant P (mg/pot)
200
100
0
300
600
Available Soil P (mg/pot)
P0
P18
P36
P72



BMP
Best Management Practices

"Best" for Doing What?

1. Maximize crop uptake per unit of nutrient applied
2. Maximize yield increase per unit of nutrient taken up
3. Maximize yield increase per unit of nutrient applied
4. Maximize farmer profit
5. Reduce greenhouse gas emissions
6. Limit nutrient run-off
7. Replenish degraded soils
8. Biofortify crops for human nutrition
9. Adapt to climate change

BMP

A Simple Principle

1. Right product(s) – Match fertilizer (and other sources of nutrients) to crop needs
2. Right time – Make nutrients available when crops need them
3. Right place – Keep nutrients where crops can use them
4. Right rate – Match amount of fertilizer to crop needs

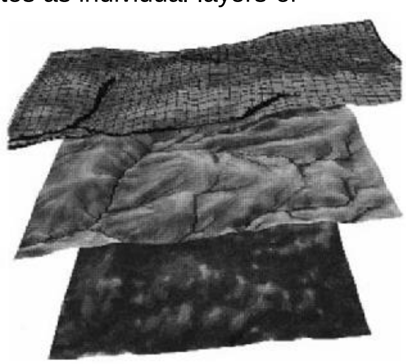
RIGHT PRODUCT	RIGHT TIME
• Soil Testing • N, P, K, secondary and micronutrients • Enhanced efficiency fertilizers • Nutrient managements plans	• Application timing • Controlled-release • technologies • Inhibitors • Fertilizer product choice
RIGHT PLACE	**RIGHT RATE**
• Application method • Incorporation of fertilizer • Buffer strips • Conservation tillage • Cover cropping	• Soil testing • Yield goal analysis • Crop removal balance • Nutrient management planning • Plant tissue analysis • Applicator calibration • Crop scouting • Record keeping • Variable rate technology • Site-specific management

- The development of information and communication technology has led to the growing awareness of
  - soil nutrient variability,
  - the possibility of higher yields,
  - improved quality,
  - and stricter environmental regulations

  requiring reduced nutrient leaching, runoff, and loss.
- Technologies used in agriculture include
  - Geographic Information Systems (GIS),
  - the Global Positioning System (GPS),
  - Remote Sensing (RS),

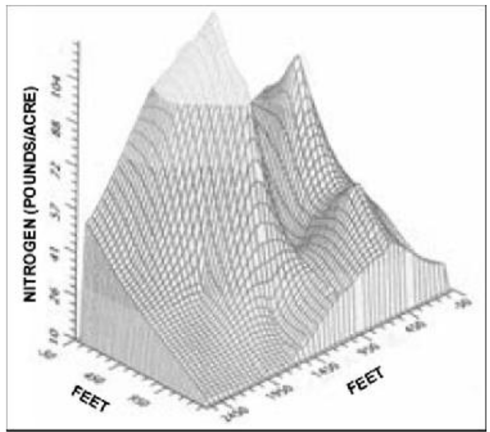
  in-field sensors, yield monitoring and mapping, hand-held computers, and variable-rate technology (VRT).

- Geographic Information Systems (GIS)
  - GIS are computer software systems designed for entering, storing, manipulating, analyzing, and displaying spatial information (Morgan and Ess, 1997).
  - Data entered into GIS include not only the 'attribute' (e.g., N application amount) of interest, but also the geographic location of the attribute on the earth's surface.
  - GIS can display multiple attributes as individual layers or combine them into one image.

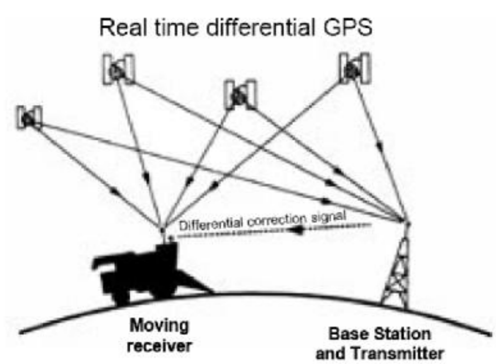


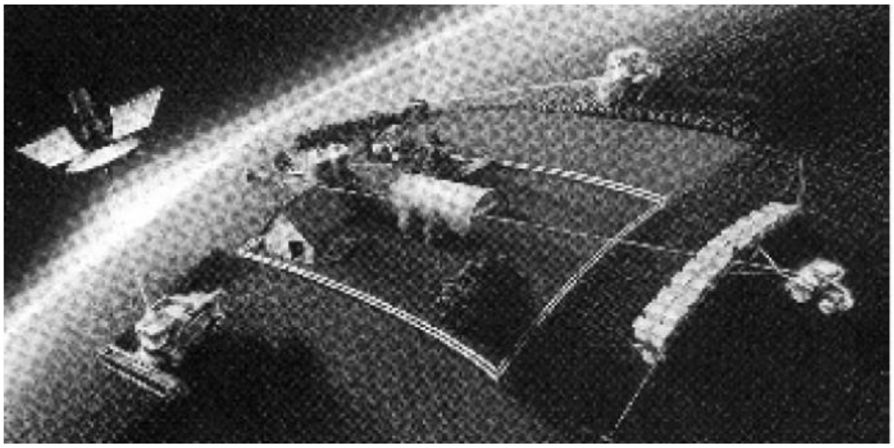
GIS layers of yield (top), topography (middle), and soil conductivity (bottom) (From Westervelt and Reetz, 2000)

- GIS can store, calculate, and model current or historical data.
  - For example, you can enter annual nitrogen (N) application rates, view changes over time, and estimate needs for the next growing season by calculating approximate nutrient changes in availability for the current crop.
- If you want a visual display of application rates, you can also use any number of GIS models (Figure 2, at left).



- Global Positioning System (GPS)
  - GPS uses satellite signals to calculate latitude, longitude, and elevation
  - Producers almost exclusively use Differential GPS (DGPS) because it is more accurate (generally within about one yard) than GPS without correction (>10 yards)
  - GPS is essential in applying other technologies (discussed later) and is often used simultaneously on several pieces of equipment

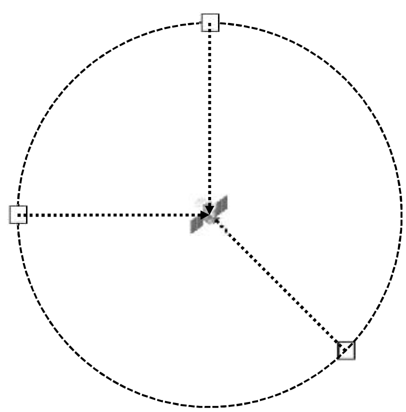




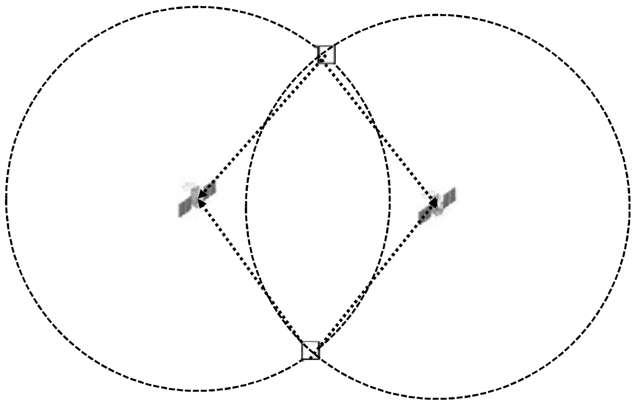
GPS satellites can be simultaneously used for multiple applications. This image shows only one of four satellites needed for accurate locations (From Morgan and Ess, 1997)

The Why do I need four satellites for GPS to work?

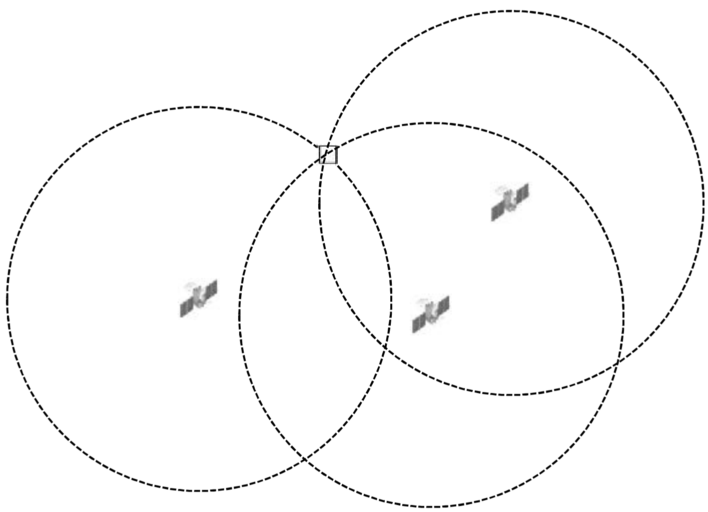
1. GPS receivers use a principle called '**trilateration**.'
2. Trilateration determines the position of an object by **measuring its distance from other objects with known locations**.
3. A GPS receiver determines its distance from a satellite by using the time it takes for a signal to travel from the satellite to the receiver.
4. If you know your distance from one satellite, you could be anywhere on a sphere surrounding that satellite (the satellite is at the center of the sphere).



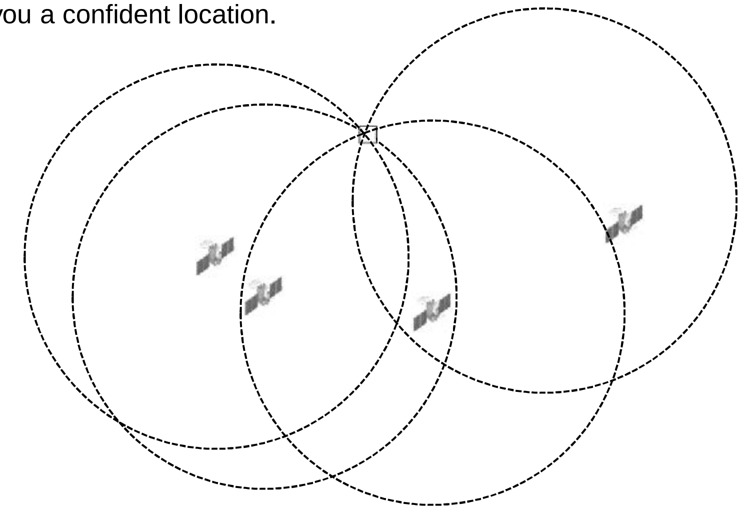
5. If you add distance information from **a second satellite**, you narrow your location to the intersection of the two spheres around those satellites.



6. Addition of **a third** sphere locates you at one of two points.



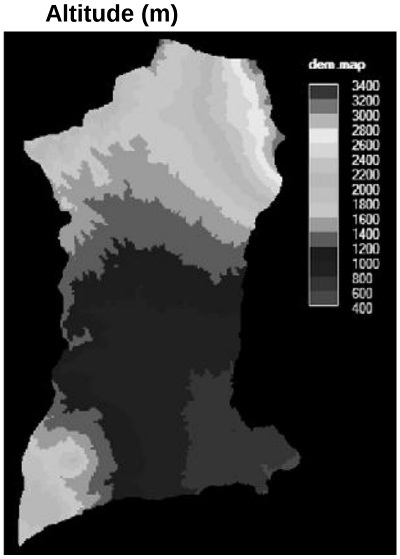
7. A fourth satellite signal eliminates one of those two points, giving you a confident location.



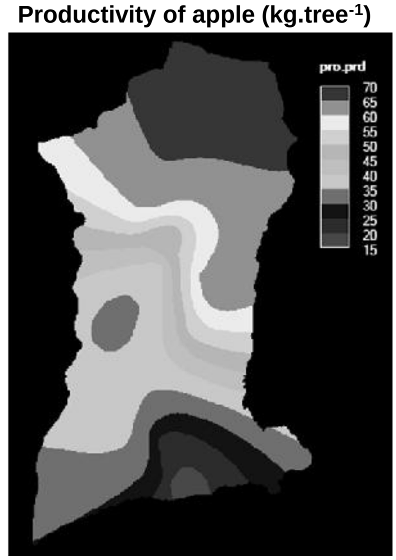
Many GPS receivers can read up to twelve satellites; as more satellites are shown on your receiver, the accuracy of your position increases (Adapted from www.montana.edu/places/gps).

APPLE IN BATU

Altitude (m)



Productivity of apple (kg.tree^{-1})



Fruit size (g.fruit^{-1}) **Soil N (%)**