Carbon Farming
vs.
Farming for Carbon

How to improve soil organic matter

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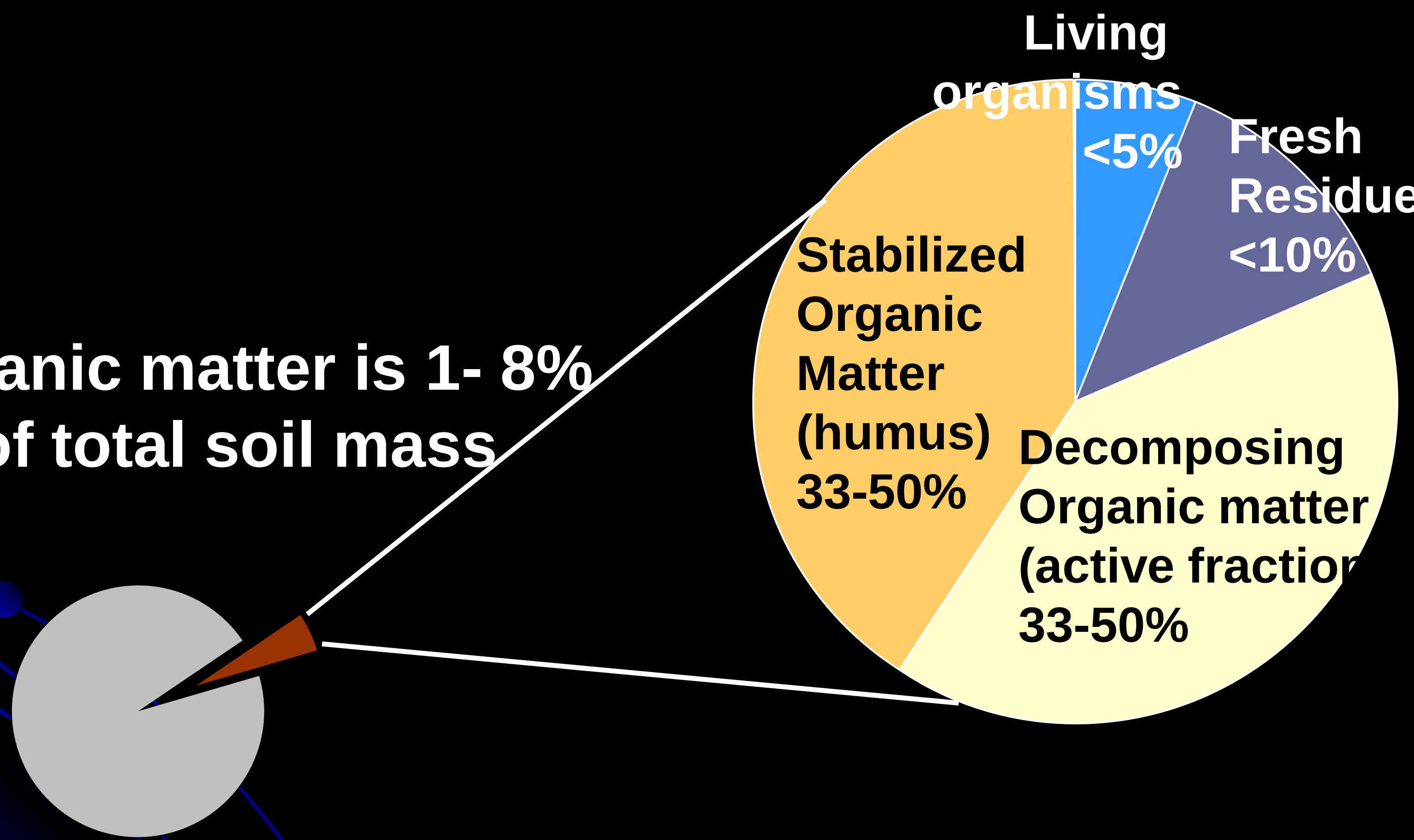
"Although managing SOM is usually not a priority in farm decision making, practices that improve SOM contribute more than any other resource to a farms long-term productivity"

Benefits of Soil Organic Matter:

- **Reservoir of plant nutrients**
- **"Food" for soil biota**
- **Soil Physical properties**
  - **Reduces soil density**
  - **Essential for aggregate formation**
  - **Improves air/water infiltration**
  - **Improves water storage**
- **Improves soil "Tilth"**
- **Reduces soil erosion**

Soil Organic Matter

Organic matter is 1- 8% of total soil mass



Soil organic matter is composed of:

- **Organic matter is the vast array of carbon compounds in soil.**
- **Originally created by plants, microbes, and other organisms,**
- **Plant materials consist of simple sugars, cellulose, hemicellulose and lignin – contain also proteins and amino sugars**

Decay Process – solution, fragmentation, decay and humification.

Humification: Chemical process, condensation will N compounds and lignin.

Carbon Farming
vs.
Farming for Carbon?

Carbon Farming vs. Farming for Carbon?


1930's

From Verle Kaiser Archive, WSU

USDA-SCS, 1942

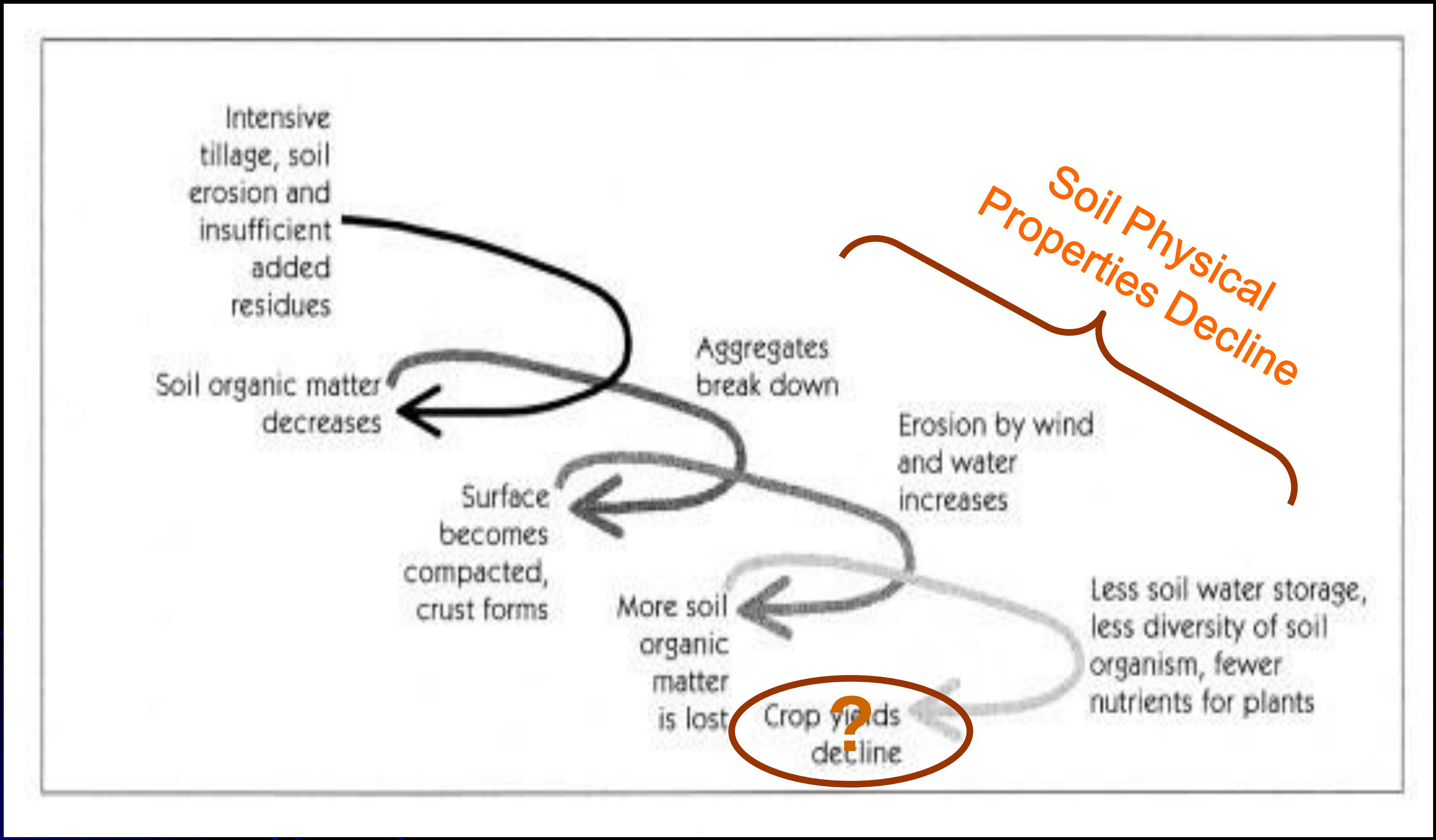
From Verle Kaiser Archive, WSU
USDA-SCS, 1942 (238 t/ac)


1970’s


1980's


2005

Soil Degradation: Farming Carbon

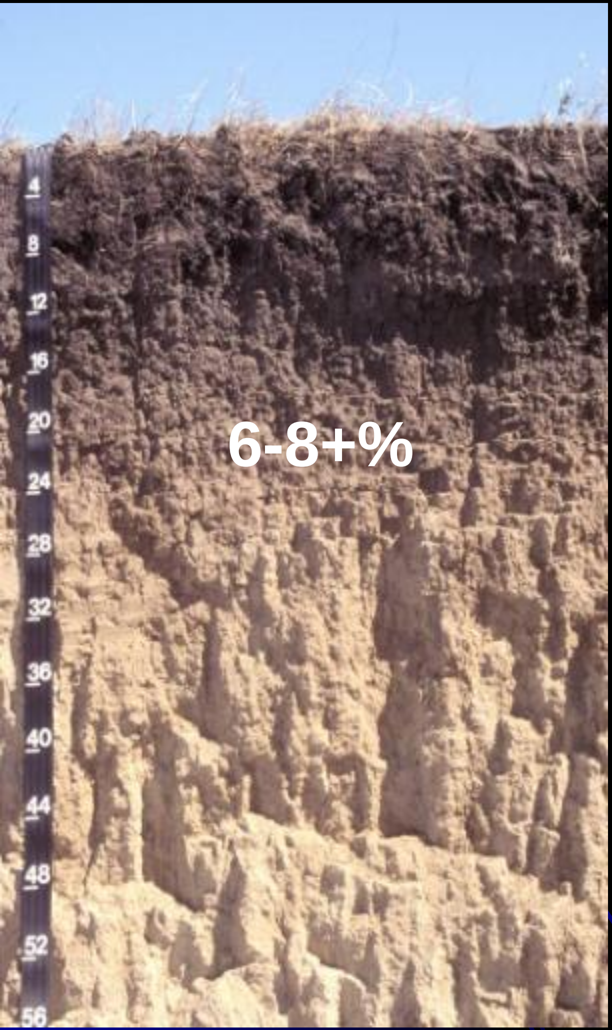


The downward spiral of soil degradation.

Adapted From Topp et al., 1995

Soil Type

Mollisol



Grasslands

Alfisol

Forests

Aridisol

Columbia Basin

USDA NRCS

Columbia Basin Soils Developed: Arid environment

Annual Precip. 6-8” (winter)

MAT 52 ^{0}F

Temp Range <32 - 110 ^{0}F

Sands - silt loam soils

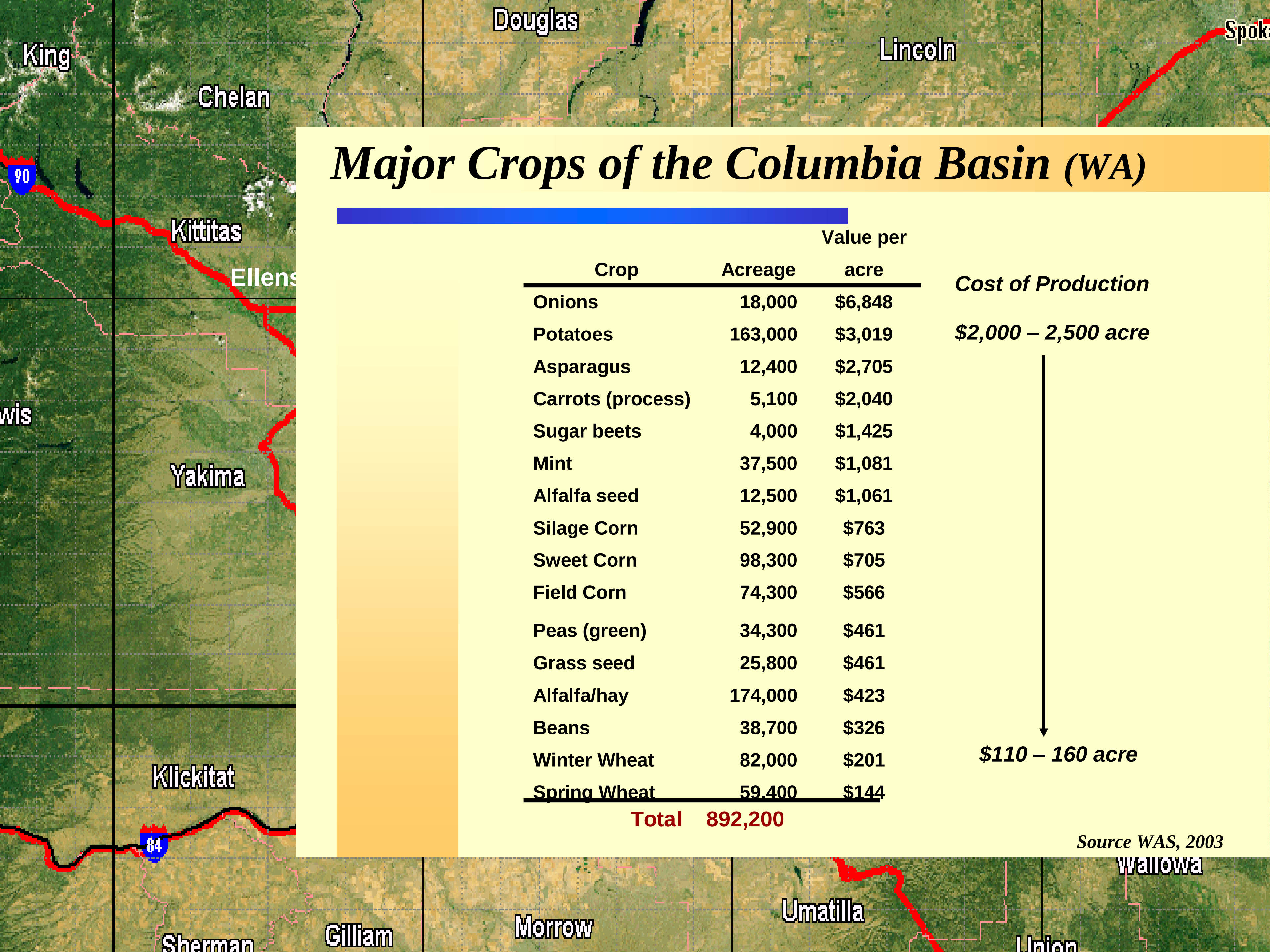
Native Vegetation: Shrub-steppe

- big sagebrush (others)
- antelope bitterbrush
- rabbit brush
- bluebunch wheatgrass
- Idaho Fescue
- Sandberg’s bluegrass
- needle grass

Annual Residue Input

Shrub-steppe 1,100 lb ac^{-1}

Cultivated 3,000 – 12,000 lb ac^{-1}



Major Crops of the Columbia Basin (WA)

Crop	Acreage	Value per acre
Onions	18,000	$6,848
Potatoes	163,000	$3,019
Asparagus	12,400	$2,705
Carrots (process)	5,100	$2,040
Sugar beets	4,000	$1,425
Mint	37,500	$1,081
Alfalfa seed	12,500	$1,061
Silage Corn	52,900	$763
Sweet Corn	98,300	$705
Field Corn	74,300	$566
Peas (green)	34,300	$461
Grass seed	25,800	$461
Alfalfa/hay	174,000	$423
Beans	38,700	$326
Winter Wheat	82,000	$201
Spring Wheat	59,400	$144
Total	892,200	

Cost of Production

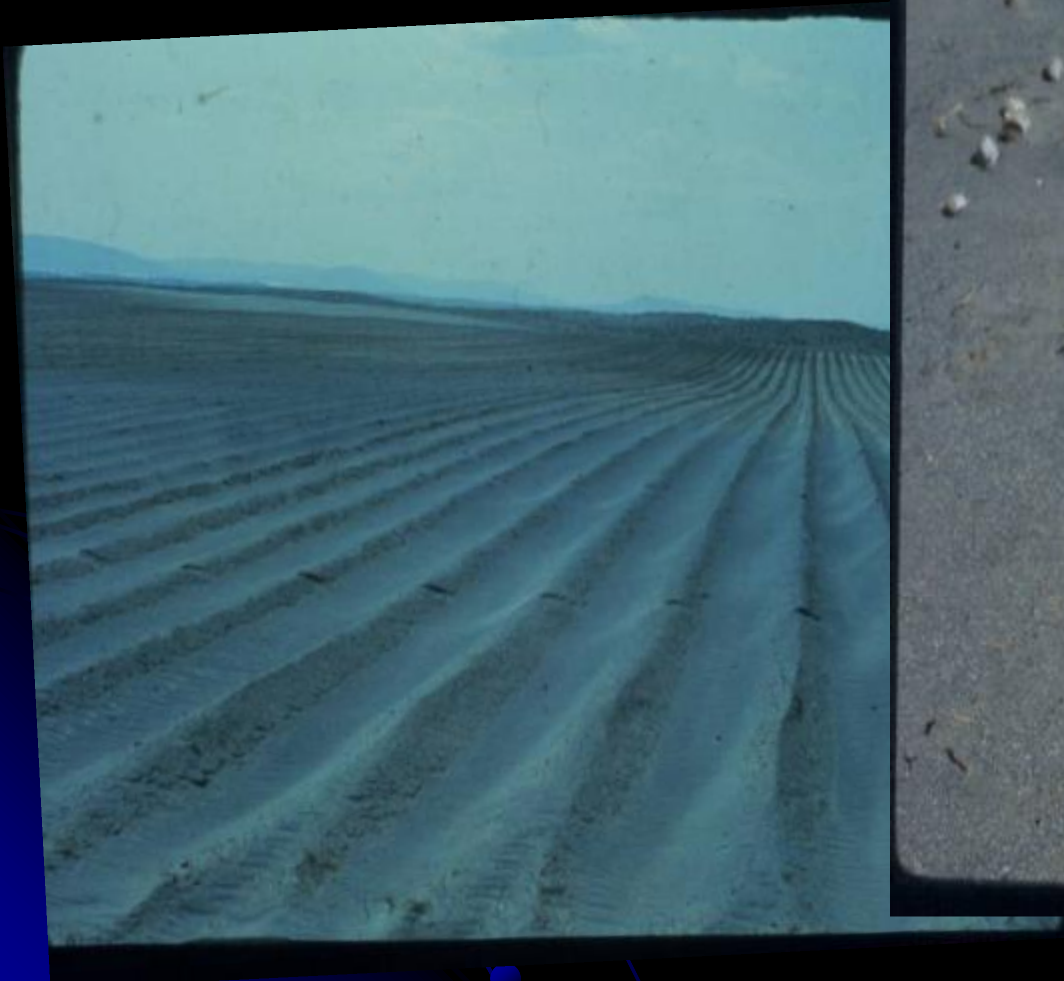
$2,000 – 2,500 acre

↓

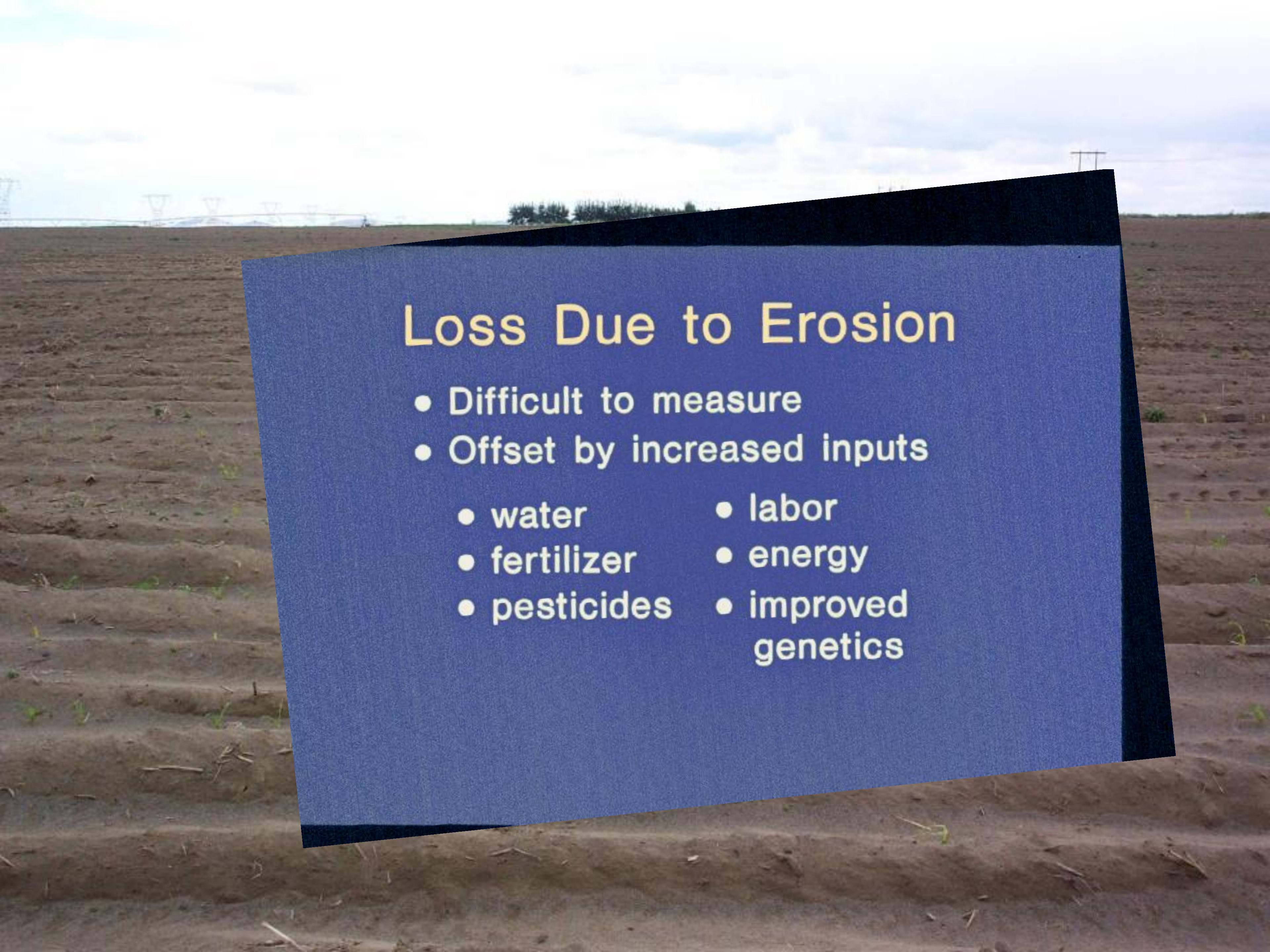
$110 – 160 acre

Source WAS, 2003

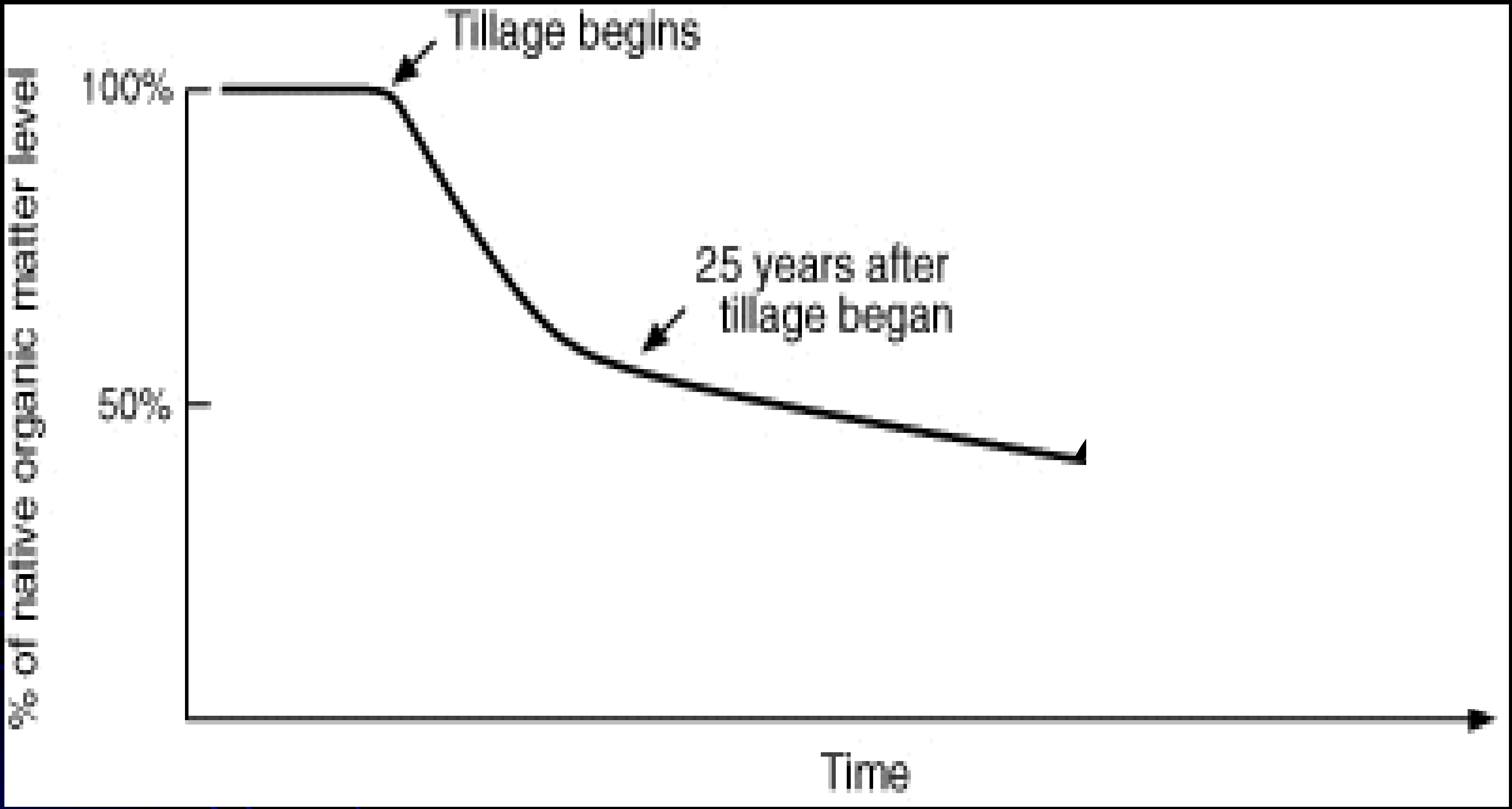
"Increased frequency of tillage and low residue crops in rotation increases soil erosion"



Photos from Bob Thornton, 1970's


Loss Due to Erosion
• Difficult to measure
• Offset by increased inputs
• water
• fertilizer
• pesticides
• labor
• energy
• improved genetics

Decline in Soil Organic Matter

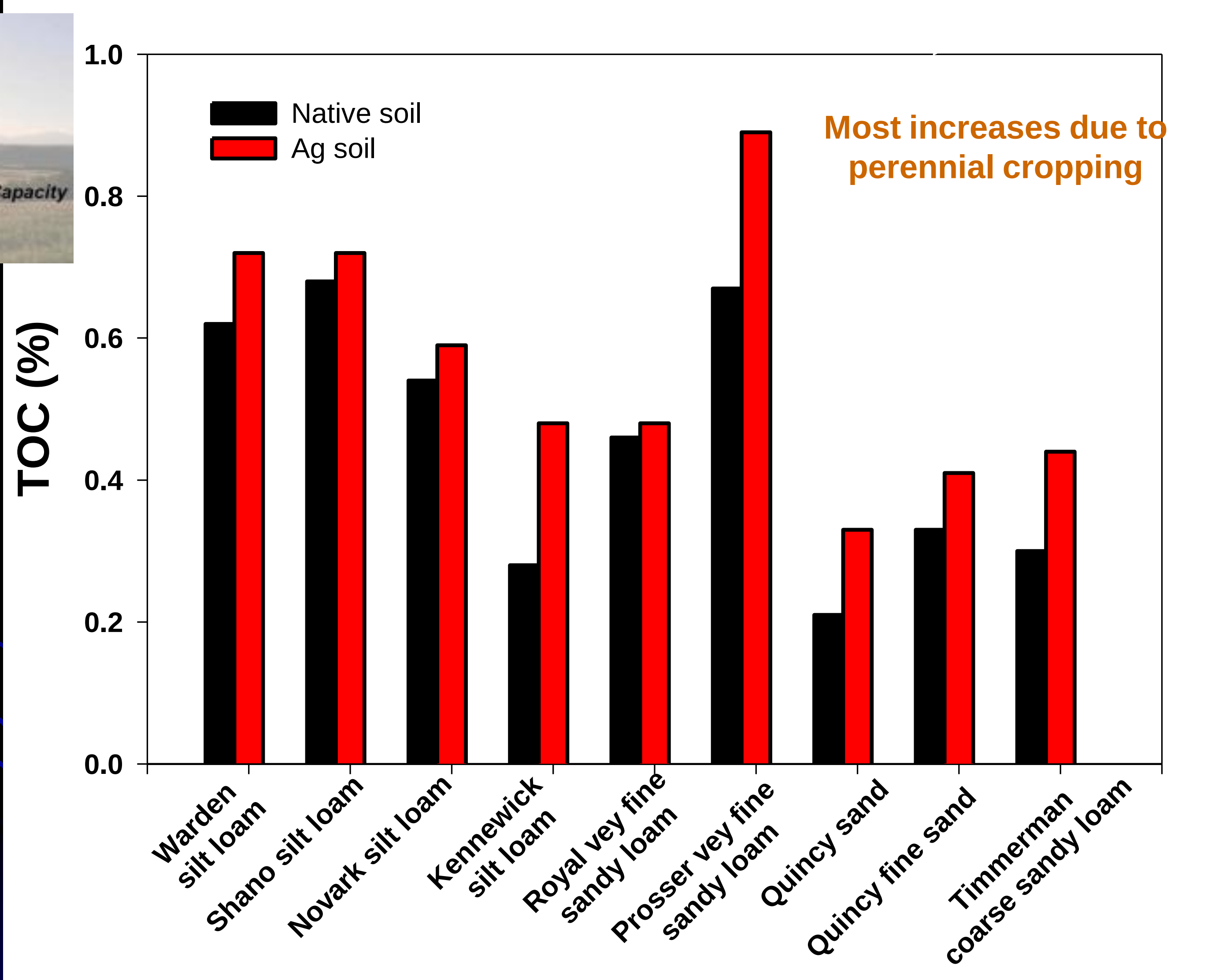


Most organic matter losses in soil occurred in the first decade or two after land was cultivated. Native levels of organic matter may not be possible under agriculture, farmers can increase the amount of active organic matter by reducing tillage and increasing organic inputs.

Management Practices Promoting Soil Organic Matter - Carbon Farming

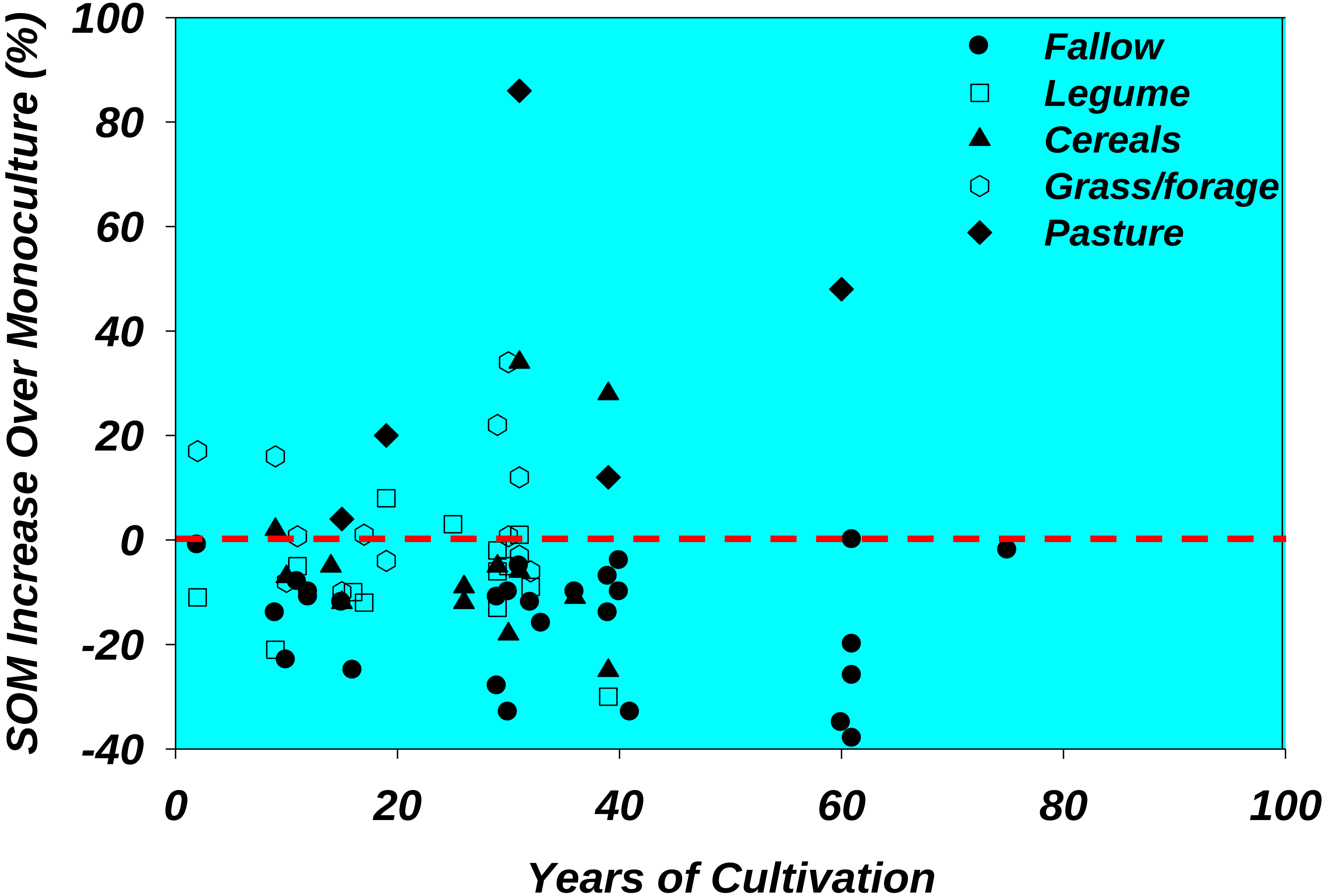
- ***Increased residue return.***
- ***Reduced tillage.***
- ***Perennial Rotations.***
  - ***Grass and alfalfa***
- ***Cover crops***
- ***Manure/Compost additions.***
- ***Elimination of bare fallow.***

Impact of Irrigated Ag on Soil Organic Carbon



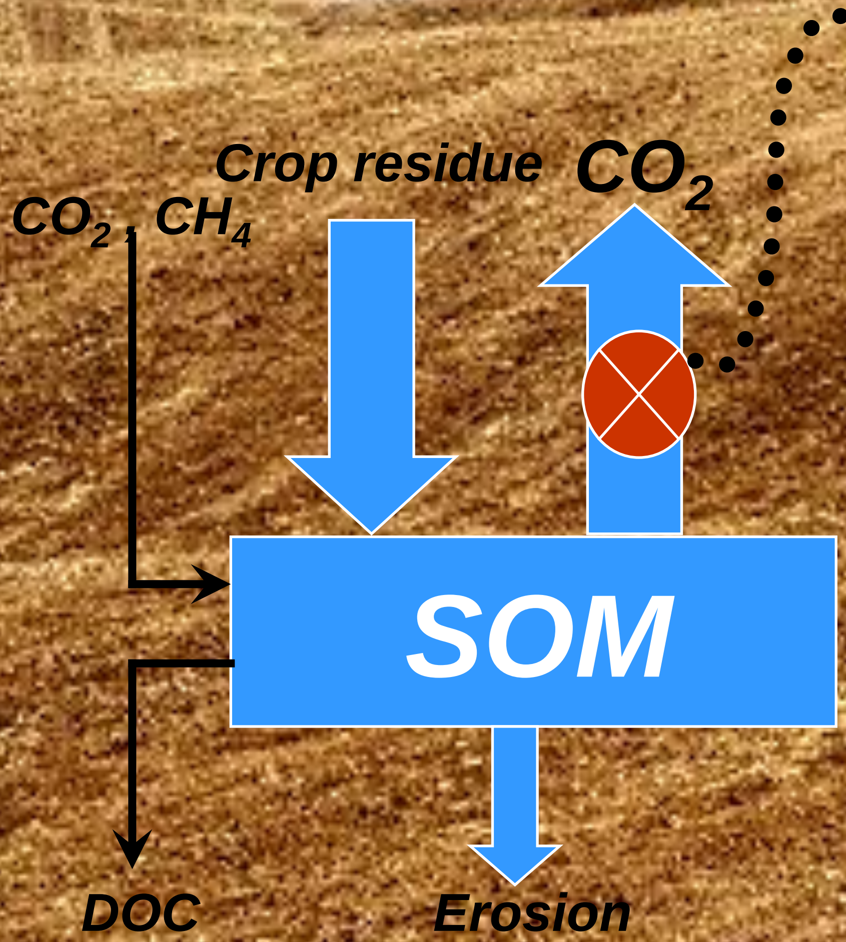
Source: WADOE Report# 99-309

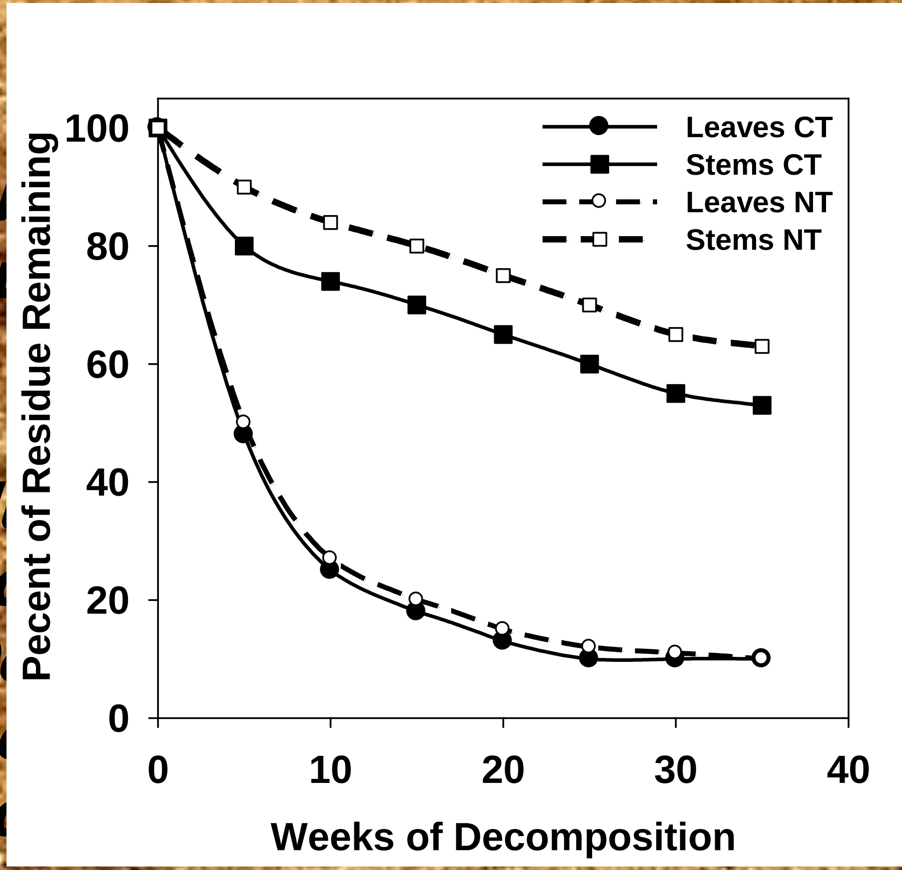
Rotation Effects on C-Storage



SOM Formation: ***Residue Decomposition***

Decomposition/Mineralization





Conservation Tillage: Managing Residues

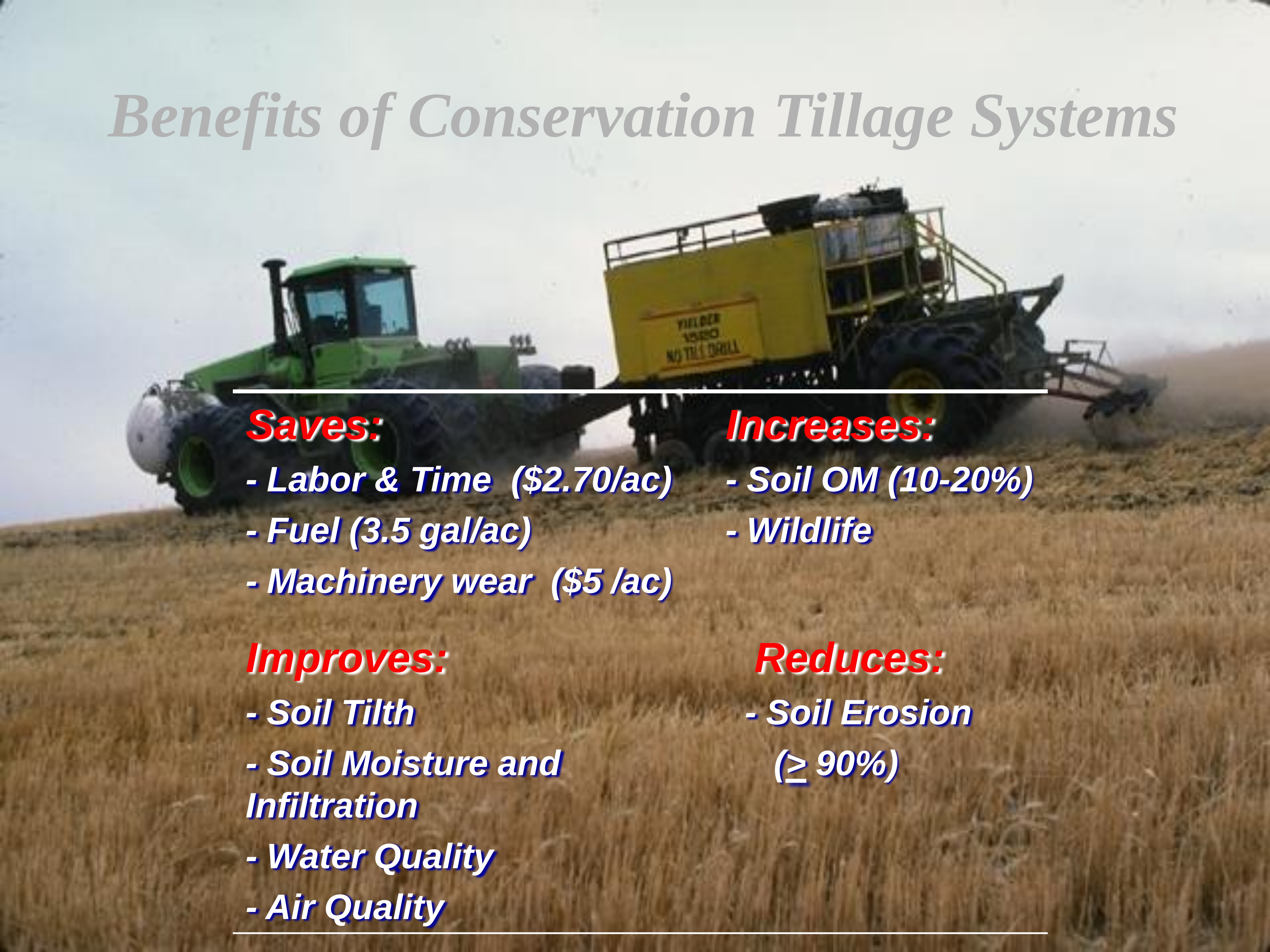
Conservation tillage is a system that "manages the amount, orientation, and distribution of crop and other plant residues on the soil surface".

At least 30% of the soil surface is covered with crop residue immediately following planting.

- Conservation tillage is an "umbrella" term for many tillage systems that are called by many different names. Commonly used are no-till, direct-seed, strip-till, ridge-till, and mulch-till.
- The goal of these systems is to maintain sufficient residue on the soil surface to reduce wind and water erosion, reduce energy use, conserve soil and water resources, reduce costly inputs and improve profits.

What practices encourage SOM: Carbon Farming

This 1914 photo shows that no-tilling wheat after soybeans is not a new idea.
JC Allin and Sons Inc/Rural Life



Benefits of Conservation Tillage Systems

Saves:
- Labor & Time ($2.70/ac)
- Fuel (3.5 gal/ac)
- Machinery wear ($5 /ac)

Increases:
- Soil OM (10-20%)
- Wildlife

Improves:
- Soil Tilth
- Soil Moisture and Infiltration
- Water Quality
- Air Quality

Reduces:
- Soil Erosion ($\geq$ 90%)


No-till potatoes 1977
WSU


Conventional
Reduced
Spring

Effect of Tillage on Potato and Sweet corn yields.

Three yr rotation: SWC-SWC-P

	Potato		Sweet Corn yr1		Sweet Corn yr2	
Year	CT	RT	CT	RT	CT	RT
	----------------------------	T ac^{-1}	----------------------------			
2001*	33.5	32.1	10.2	8.8	9.9	8.8
2002*	32.6	32.5	7.5	7.4	7.5	6.7
2003	33.1	31.2	†4.5	4.1	4.7	4.4
2004	27.8	27.0	9.9	10.4	9.3	9.4
2005	37.7	38.6	12.5	10.2	10.0	7.0
2006	36.3	36.1	11.5	10.4	10.1	9.0
2007	31.0	30.9	12.0	10.6	11.1	9.4
2008	40.9	39.7	13.5	13.2	12.5	9.7
Average	34.1^{NS}	33.5^{NS}	11.0	10.1	10.0	8.6*

Potato variety – Ranger Russet. † Field Corn. (150-180 bu/ac).

Reduction of tillage maintains crop residues

- Creates changes in soil biological, chemical and physical properties
  - not independent of one another
- Simplest change in physical condition is due to a “dilution effect”
- *Increase in SOM*
- Stimulate Microbial Activity
  - Increased respiration and biomass.
  - Production of polysaccharides and mucigels bind soil particles together.
  - Increase of fungal hyphae further bind small aggregates into large aggregates.

Properties of Soils: Influenced by tillage

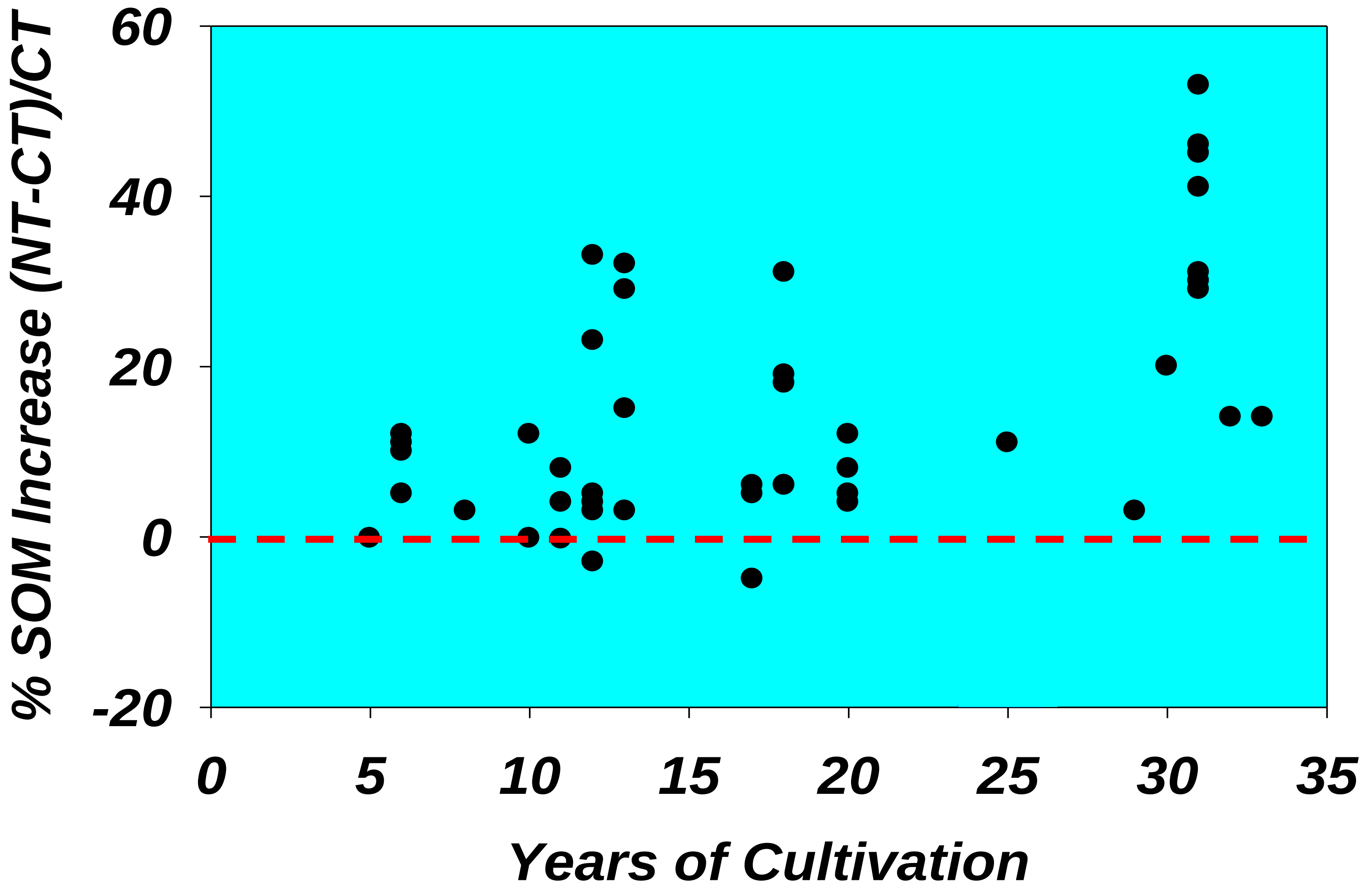
Reduced tillage

- SOM ↑
- Soil temperature ↓
- Bulk density ↓
- Aggregation and Aggregate Stability ↑
- Total Porosity- pore size distribution ↑
- Soil resistance to penetration ↓
- Water Infiltration ↑
- Water holding capacity and retention ↑
- Microbial populations ↑

Where do changes occur?

Changes under reduced tillage/ or high residue farming typically occur in the surface 3-4 inches of soil.

Tillage Effects on C-Storage



Building SOM with Organic Amendments

Types of Soil Organic Amendments

- **On farm wastes:**
  - **- manure, crop residues, spoiled straw, hay and silage**
- **Municipal wastes:**
  - **- yard debris, and biosolids (sewage sludge)**
- **Organic wastes from food processors:**
  - **- vegetable, meat, fish, dairy**
- **Organic wastes from paper mills and timber industry:**
- **Composts**
- **Other?** **Humic/Fulvic Acids**

Maintaining residues builds SOM:

- **Reservoir of plant nutrients**
- **“Food” for soil biota**
- **Soil Physical properties**
  - **Reduces soil density**
  - **Essential for aggregate formation**
  - **Improves air/water infiltration**
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- **Improves soil “Tilth”**
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Input of Organic Amendments

- Creates changes in soil biological, chemical and physical properties
  - not independent of one another
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Organic Amendments and their C:N ratios.

Organic amendment	C:N
High in carbon	
Corn stalks	60-70
Straw	40-150
Corn silage	40
Fall leaves	30-80
Sawdust	200-700
Brush, wood chips	100-500
Bark (paper mill waste)	100-130
Newspaper	400-800
Cardboard	500
Mixed paper	150-200
High in Nitrogen	
Hay	15-30
Dairy manure	5-25
Poultry manure	5-15
Hog manure	10-20
Cull potatoes	18
Vegetable wastes	10-20
Coffee grounds	20
Grass clippings	15-25
Municipal biosolids	9-25

Cooperband, 2002

Average nutrient content from manures.

Type of Manure (not composted)	lbs. per ton (solid) lbs. per 1000 gallons (liquid)		
	N	P_2O_5	K_2O
Dairy, solid	10	5	9
Beef, solid	14	9	11
Swine, solid	14	10	9
Duck, solid	17	21	30
Chicken, solid	40	50	30
Turkey, solid	40	40	30
Sheep, solid	26	18	40
Horse, solid	10	6	10
Dairy, liquid	24	9	20
Veal calf, liquid	15	10	25
Beef, liquid	20	9	20
Swine, liquid indoor pit	50	42	30
Swine, liquid outdoor pit	34	16	20
Swine, liquid, farrow-nursery indoor pit	25	23	22
Poultry, liquid	16	10	12

Cooperband, 2002

Residue Nutrient Content

	Approximate Content (lbs ton^{-1})			
	Wheat	Corn	Potato	Peas
Nitrogen	8-12	15-30	30-40	25-30
Phosphorus	3-5	3-5	6-12	5-6
Potassium	27-40	30-50	80-120	30-35
Sulfur	2-3	2-3	4-8	5-6
Calcium	4-5	4-8	12-25	3-4
Magnesium	2-3	3-5	8-20	2-3

USDA UNITED STATES DEPARTMENT OF AGRICULTURE ars

Cover Crop:

"Any crop grown primarily to provide ground cover to improve soil properties, rather than providing a harvestable yield".

Cover crops include:

- **Legumes (vetch, clovers,peas)**
- **Small grains (Rye, triticale, wheat)**
- **Sudan grass**
- **Brassica's (mustard, arugula)**

Historical Timeline of Cover Crops in Columbia Basin

wind erosion control

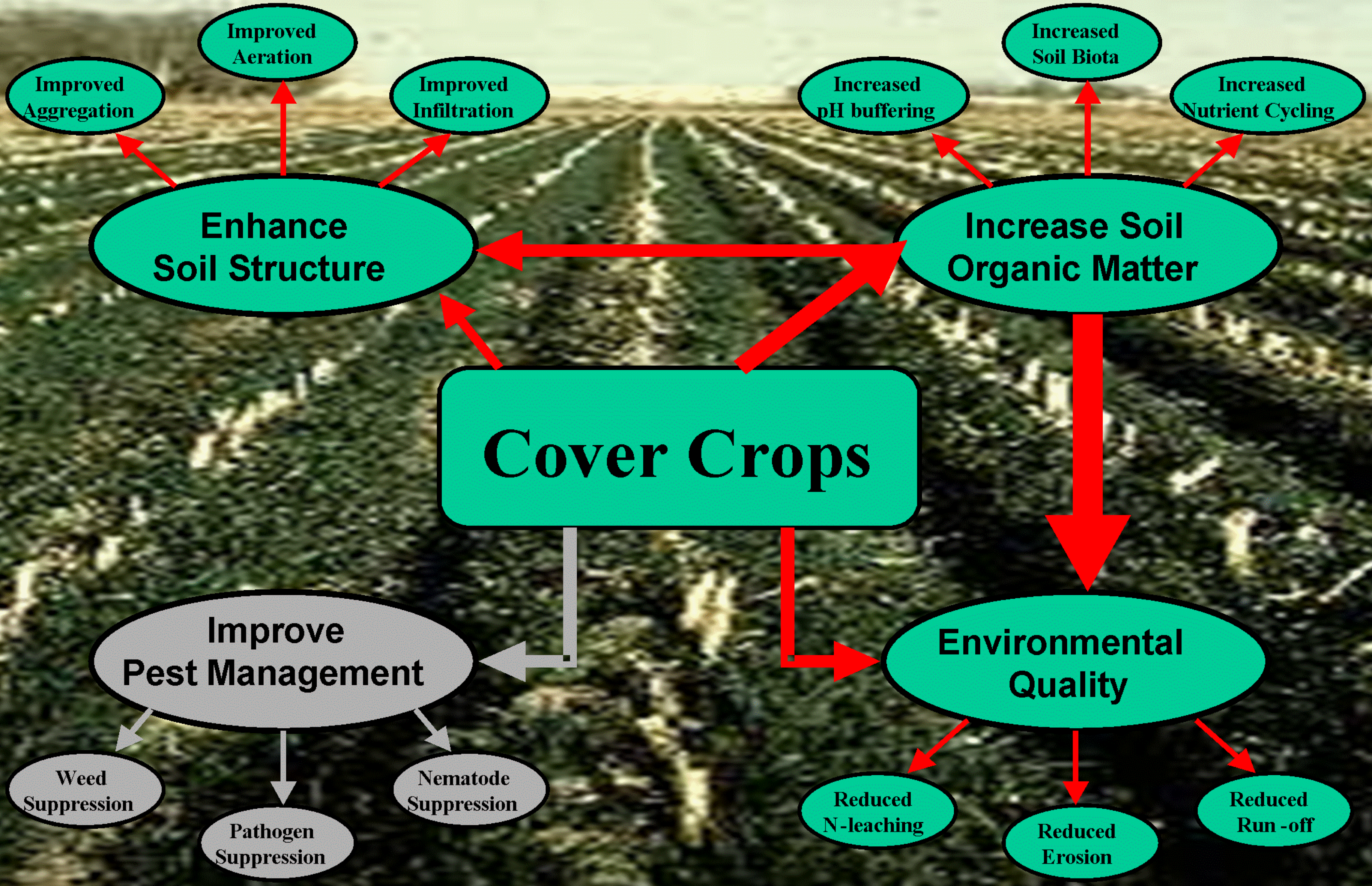
N supply with legumes

weed, disease, nematode suppression

nitrate recovery and recycling

1950's-60's — **1970's-80's** — **1990's**

Benefits of Cover Crops



How Cover Crops/Green Manures Work to Reduce Disease:

- *Crop rotation* → *Changes field conditions* / → *Increase diversity of crops*
- *Competitive Exclusion* → *Competition Resources* — *Energy*, *Space*, *Nutrients*
- *Biofumigation* — *Glucosinolates* + *enzymes* → *ITCs*
- *Antagonism/Predation*

Soil Community Response to Cover Crops:

Bio-fumigation: Brassicas/Sudangrass/Vetch

- inhibit Verticillium dahliae on potato

- suppresses Columbia root-knot nematode

- reduces incidence of black root rot of cotton

-reduces incidence of corky root of tomato

Increases the predation and feeding of:

- ***Free-living nematodes***
  -Fusarium, Rhizoctonia, root knot cyst nematode
- ***Collembola***
  - Rhizoctonia solani, Pythium
- ***Mites***
  -Rhizoctonia

Other Responses:

Increase microbial and fungal populations:

- ***Competition and/or suppression***
  - ***- Non-pathogenic vs Pathogenic (Fusarium)***
  - ***- Pasteuria penetrans vs nematodes***
- ***Direct Antagonism***
  - ***- Pythium vs Psuedomonas spp.***
- ***Production of hormones, antibiotics***
  - ***- Protozoa produce auxins***
  - ***- siderophores***

Conservation Tillage Creates Habitat Shift

Biological Diversity Increases

Microflora Microfauna Macrofauna Insects Animals

Ratio of Microbial Populations between no-till and conventional till.

	Ratio of microbial populations (NT/CT) with depth		
Microbial Group	***0-3 in.***	***3-6 in.***	***0-6 in.***
Total Aerobes	***1.35******	***0.71******	***1.03***
Fungi	***1.57******	***0.76*****	***1.18***
Actinomycetes	***1.14******	***0.98***	***1.08***
Aerobic bacteria	***1.41******	***0.68******	***1.03***
NH_4 ***oxidizers***	***1.25****	***0.55*****	***0.89***
NO_3 ***oxidizers***	***1.58****	***0.75*****	***1.14***
Facultative Anerobes	***1.57****	***1.23***	***1.32****
Denitrifiers	***7.31****	***1.77***	***2.83***

Doran et. al., 1993

Influence of residues and reduced tillage on plant disease

Table 1.Field and sweet corn diseases.

Disease	Pathogen lives in	Trend/w reduced till	Rotation interval
Seed rot	Res./soil	unknown	1-2 yr
Stalk rot	Res./soil	unknown	1-2 yr
Smuts	Soil/plant	NC	NA
HPV	Mite	NC	NA
MDV	Aphid	NC	NA

Table 3. pulses (peas, beans, lentils).

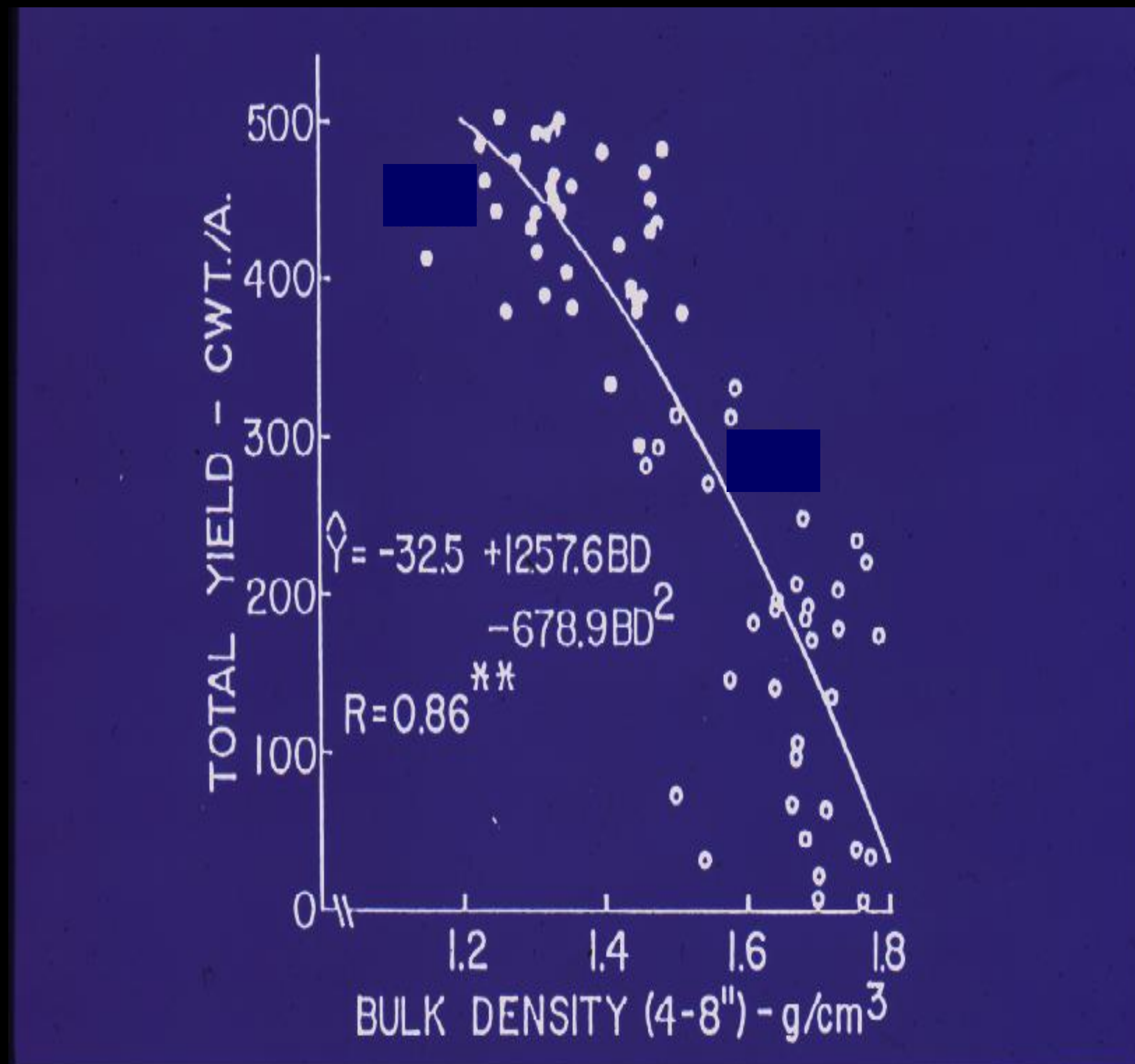
Disease	Pathogen lives in	Trend/w reduced till	Rotation interval
Ascochyta	Res./seed	Increase	2 yr
Sclerotinia	Soil	Decrease	3+ yr
Anthracnose	Res./seed	Increase	3-4 yr
Damping off	Res./soil	Increase	3+ yr
Botrytis rot	Res./seed	Increase	2-3 yr
Powdery mildew	Residue	NC	3-4 yr

Table 2. Wheat diseases.

Disease	Pathogen lives in	Trend/w reduced till	Rotation interval
Root rot	Res./soil	Decrease	2-3 yr
Pythium	Res./soil	NC	3-4 yr
Ceph. stripe	Res./soil	Varies	2-3 yr
Take-all	Residue	Varies	1-2 yr
Leaf Spot	Residue	Increase	1-2 yr
Rusts	plants	NC	NA
Smut	Seed	NC	NA
Bunt	Soil/seed	NC	NA

NC-No change, NA- Not applicable.
From Krupinsky, et al., 1997.

Soil Compaction:



Compaction is a major source of yield reduction.

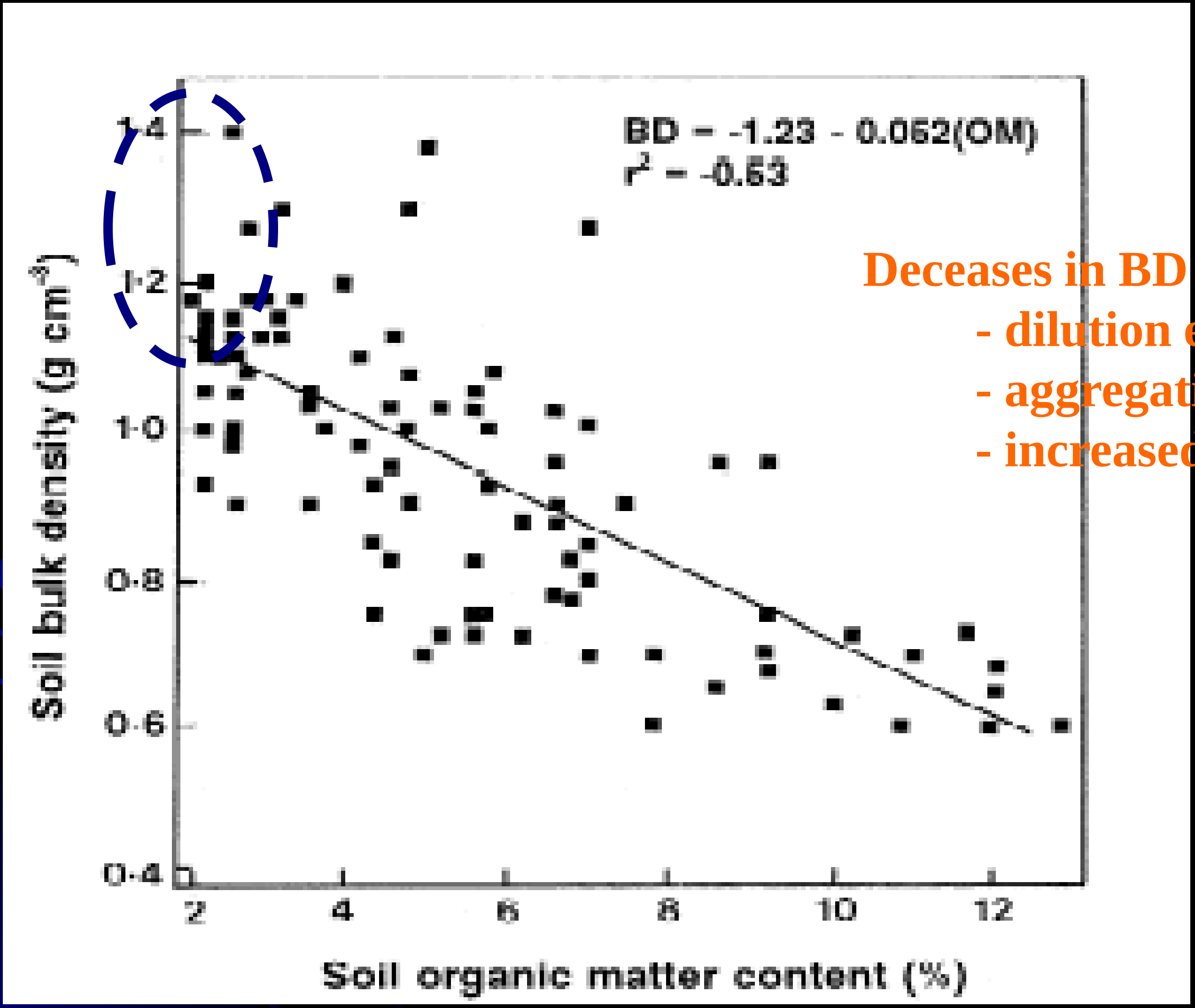
- **Restricts root growth.**
  - **- limits water availability**
  - **- limits nutrient availability**
- **Limits aeration.**
  - **- poor root health**
  - **- increased root pathogens**
- **Limits tuber growth.**

Stimulation of the soil microflora:

Changes in Nutrient Cycling:

- **Increases immobilization of N, P, S, etc.**

Relationship between bulk density and organic matter content

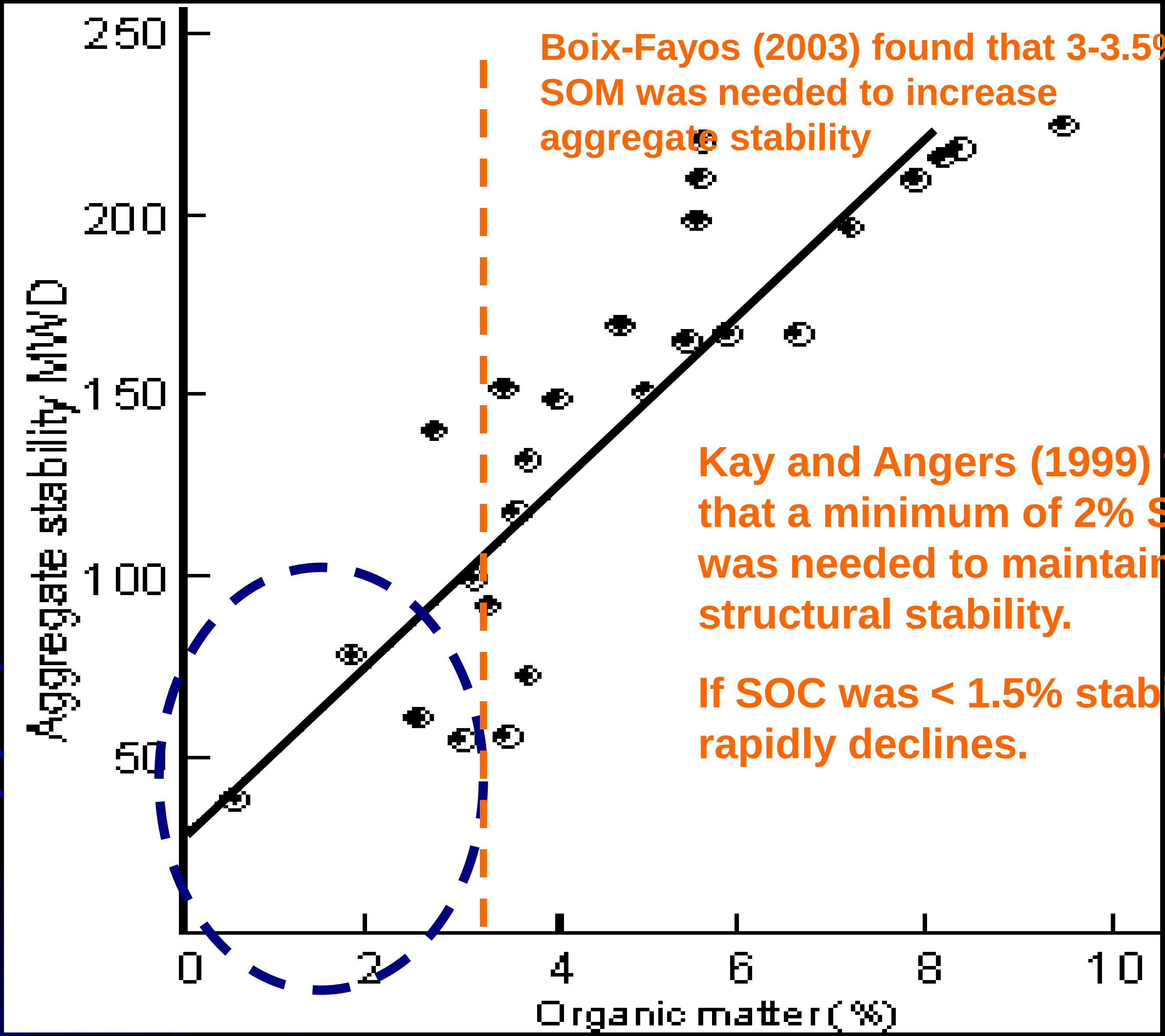


Deceases in BD due to:

- dilution effect
- aggregation
- increased porosity

From Weil and Kroontje, 1979

Relationship between aggregate stability and organic matter content.



Boix-Fayos (2003) found that 3-3.5% SOM was needed to increase aggregate stability

Kay and Angers (1999) found that a minimum of 2% SOM was needed to maintain structural stability.

If SOC was < 1.5% stability rapidly declines.

From Chaney and Swift, 1984

Summary: Successful Adoption

Change perspective on how a field should look.

Change perspective on how crops are managed.

Determine system that works for each producer.

System will have to be fine tuned to fit:

- *- soils*
- *- growing conditions*
- *- grower management abilities*
- *- different crop varieties*
- *- longer rotations, crop selections.*

- *Cropping system choices impact weed related issues in production.*

Resources:

- *The Soil Biology Primer, SWCS.* *www.swcs.org*
- *Sustainable Agriculture Research and Education Program.* *www.sare.org*
- *ATTRA – Appropriate Technology Transfer for Rural Areas.* *www.attra.org*
- *WSU Crop and Soil Sciences.* *www,wsu.edu*