# Control of Soil Erosion:
## Practices and Strategies for Sustainable Development of Agriculture in Northeast China

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# Outline

- Introduction
- Status of Northeast China
- Current scenario of water erosion
- Negative impacts of soil erosion
- Practices and strategies for soil erosion control

## Importance of Soil

- Living, dynamic, precious, natural resource
- Supports life
- Decomposes waste
- Stores heat
- Exchanges gases
- Home to macro and micro-organisms
- Material for construction, medicine , and art
- Cannot be replaced in the short-term

## Soil Problems from Agriculture

- Limited amount of soil for growing food
- Can be
  - Eroded
  - Polluted
  - Destroyed
- 11% vegetative area
- 38% cultivated area

## Soil and Soil erosion

- Soil erosion accounts for 82% of human-induced soil degradation, affecting 1,643 million hectares

  --- Oldeman, 1994

- 24 billion tons of topsoil lost annually, equivalent to 9.6 million hectares of land

  --- Bakker, 1990

## Soil and Soil Erosion

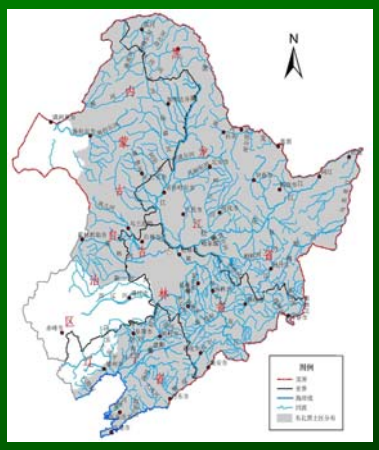
- Soil erosion is the top environmental issue in China

  ---- Liu & Yan, 2009

- Yield suppression has been a serious problem threatening the future sustainability of agriculture in NE China

  ---- Liu, 2004

# Importance of Northeast China




- Three Provinces and part of Inner Mongolia
- Total land acreage
  1.24 million $km^2$
  13% of China
- Cultivated land
  0.243 million $km^2$
  14.1% of China

# Bread basket of China

- Total grain production 76 billion kg in 2007
  -- 15.1% of China total
- Corn: 31%
- Soybean: 56%
- Rice: 9.6%
  -- 43% of Japonica rice in China
- Commodity grain
  -- 1/3 of China
- Commodity percentage 60%
- Feed 216 million urban residents annually

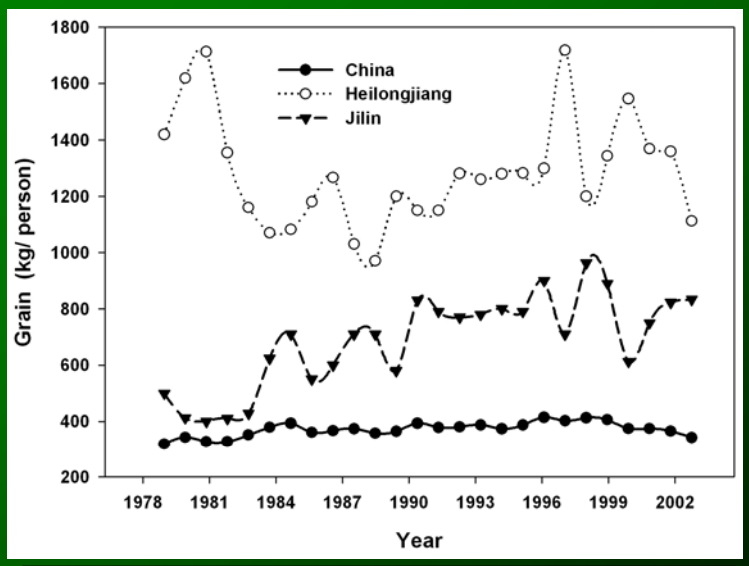


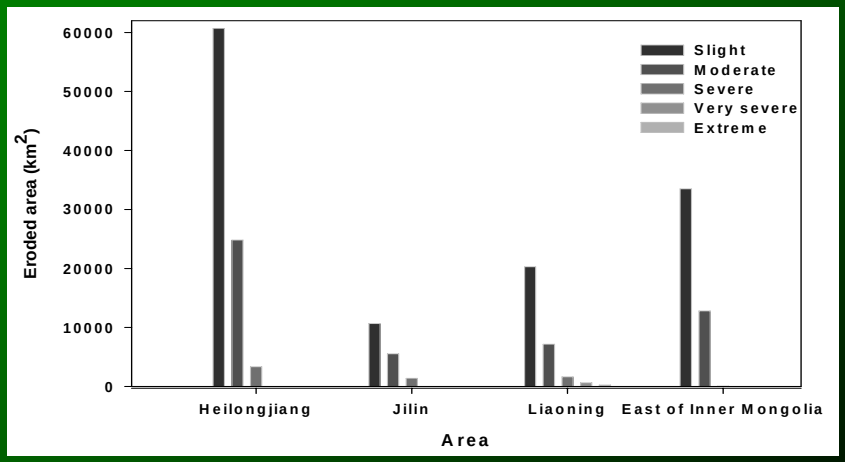

Figure 1 Grain per capita in China and Northeast China

## *Current scenario of water erosion*

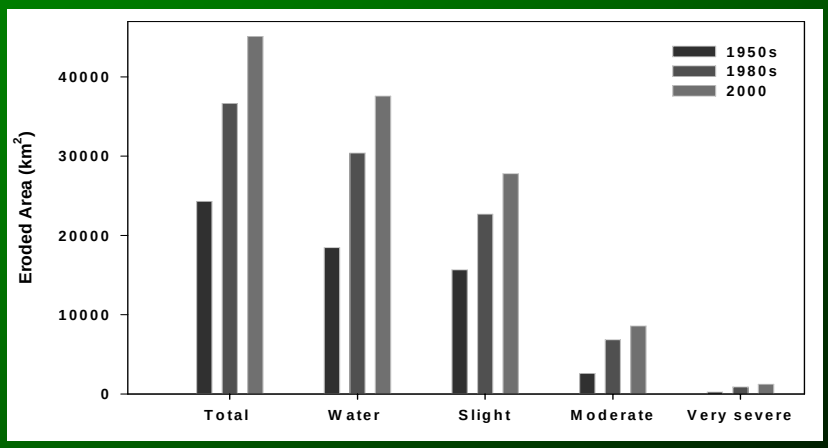
- Soil erosion mostly from water erosion
- Total water erosion of 177,000km$^2$
  - 50% in Hei-long-jiang
  - 23% in eastern Inner Mongolia
  - 17.2% in Liao-ning
  - 9.8% in Ji-lin
- 17.2% of the total area

## Distribution of water erosion area and erosion severity classes from different province

Majority of the area in the range of slight class

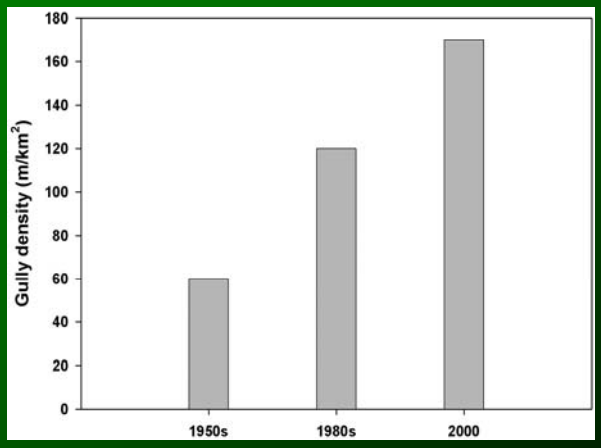



## Changes of soil erosion area in typical Black soil region of Hei-long-jiang province

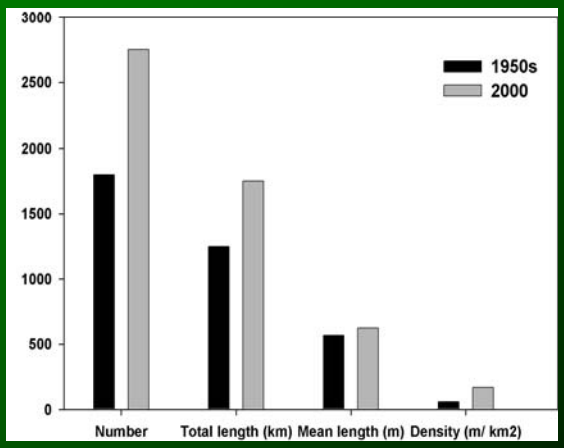



Erosion area expanding with slow rates with increased intensity

Gully density changes from the area of 118,736 km$^2$ in Hei-long-jiang



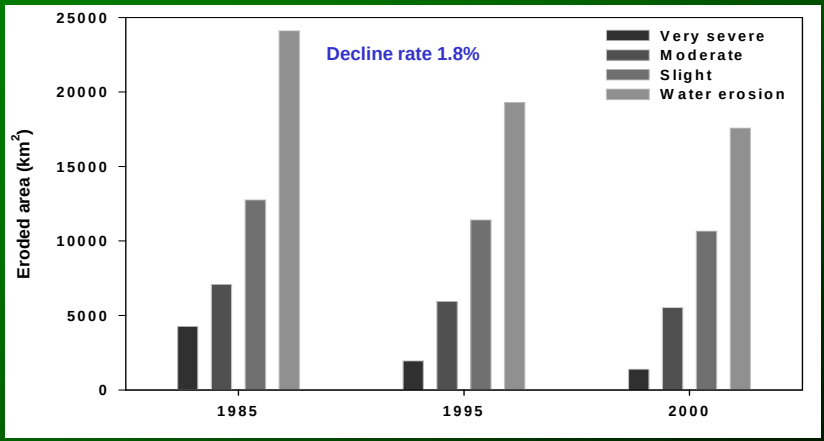

# Number, length of gullies in typical black soil region



# Positive trend since 1985

- Ji-Lin and Liao-Ning Provinces
- Annual declining rate of 1.8% in Ji-Lin
  - 60.7%-slight
  - 31.4%-moderate
  - 7.9%-severe

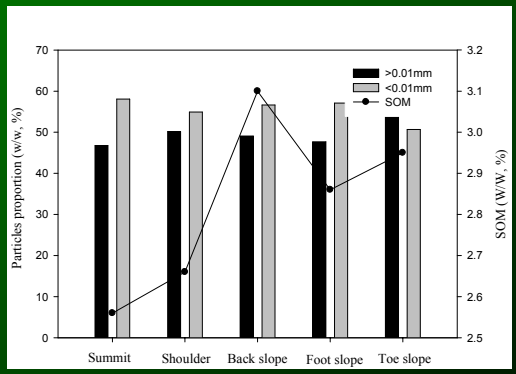
# Changes of water erosion since 1980s in Ji-lin province（km$^2$）



# *Negative impacts of erosion*

- Soil loss severe in summit, followed by shoulder and back slope
- Contents of clay particles were greater than sand particles in summit, shoulder or back slope

  --Yan & Tang, 2005




# Changes of soil properties

| Severity of erosion | Bulk density ($g/cm^3$) | Field capacity (%) | Infiltration rate $k_{10}$ (mm/min.) |
|---|---|---|---|
| No erosion | 0.79 | 57.7 | 10.55 |
| Slight | 0.93 | 52.6 | 8.74 |
| Moderate | 1.04 | 49.6 | 5.34 |
| Severe | 1.09 | 46.2 | 4.45 |
| Extreme | 1.35 | 28.0 | 1.63 |

## Changes of soil enzymes

| Soil | Urease ($NH_3$-Nmg/g soil) | Phosphatase (phenol mg/g soil) | Invertase (0.1mol/L$Na_2S_2O_3$mg/g soil) |
|---|---|---|---|
| Non-eroded | 1.010 | 0.307 | 5.060 |
| Eroded | 0.990 | 0.254 | 4.060 |

## Changes of soil microorganism

| Soil | Bacteria | Actinomyces | Fungi | Total |
|---|---|---|---|---|
| Non-eroded | $5.829\times10^6$ | $3.049\times10^5$ | $2.035\times10^4$ | $616.13\times10^4$ |
| Eroded | $4.455\times10^6$ | $2.495\times10^5$ | $3.475\times10^4$ | $473.53\times10^4$ |

## Changes of thickness in top soil layer

- 44 cm in 1982
- 30 cm accounted for 41% in 2002
- 18-24 cm in 3-5 ° sloping farmland
- 12-15 cm in 5-8 ° sloping farmland

## Erosion rate and soil loss

- 1.3 mm/a in 3-5° sloping farmland
- 2.2 mm/a in 5-8° sloping farmland
- Soil Loss

  --- 78t/ $hm^2 \cdot a$ in 5° sloping farmland

  --- 221t/ $hm^2 \cdot a$. in 15° sloping farmland

## Harmful effect of soil erosion on topsoil layer

- 23000 $km^2$ of sloping farmlands will be removed within 100-200 years
- 30,500 $km^2$ of sloping farmlands will be removed within 50-100 years
- 5,600 $km^2$ of sloping farmlands will be removed within 50 years.

## Trend of soil erosion

- Expected to increase with increase in
  - --- slope steepness
  - --- slope length
- As a result of
  - --- respective increase in velocity
  - --- volume of surface runoff

## Changes of soil organic matter

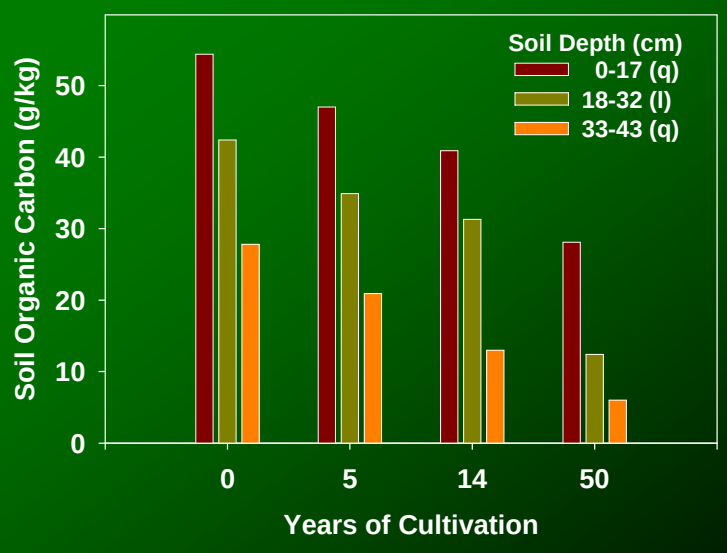
- Soils with less than 2% SOC are considered erodible

  ---- Evans, R. 1980
- Soil erodibility decreases linearly with increasing SOC over 0-10%

  ---- Voroney, R.P et al. 1981

## Soil organic matter before reclamation

- 8-10% in Hei-long-jiang Province
- 5-6% in Ji-lin Province
- Examination on four fields with different cultivation histories in Hei-long-jiang Province
  - Uncultivated soil
  - 5-year cultivation
  - 14-year cultivation
  - 50-year cultivation

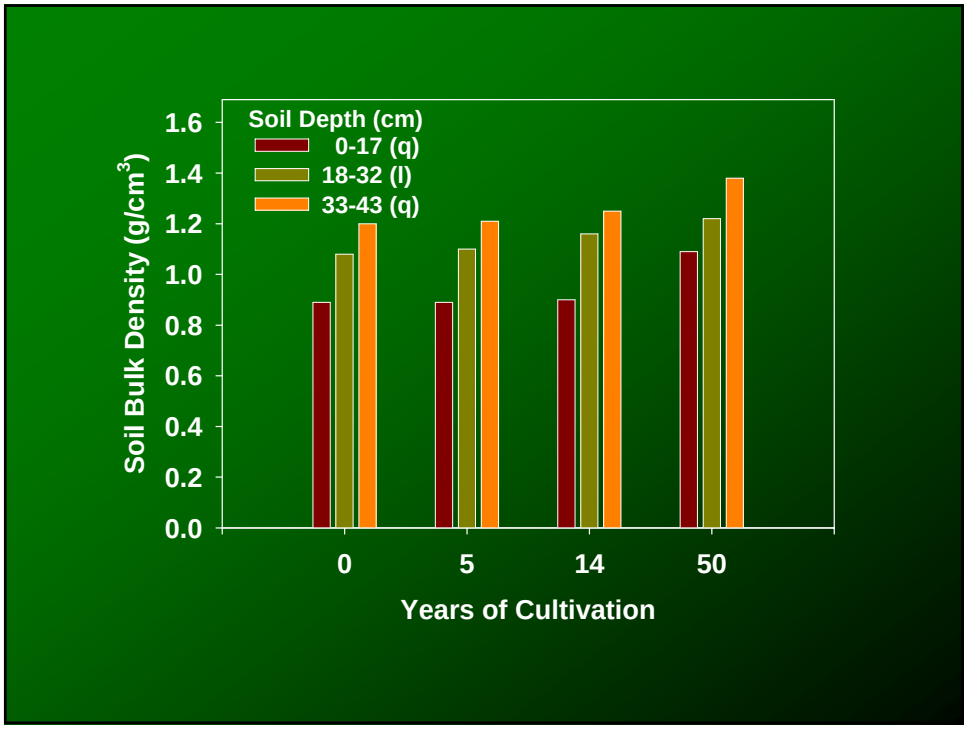


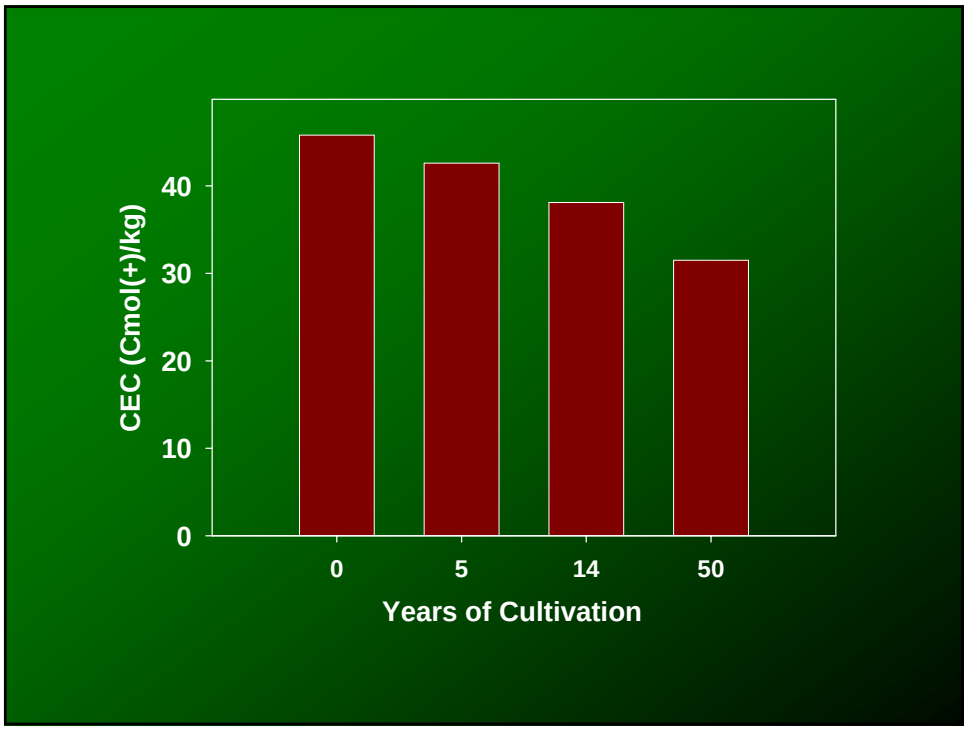

# Average SOC loss per year

- 2300 kg/ha between 0 to 5 years
- 950 kg/ha between 5 to 14 years
- 290 kg/ha between 14 to 50 years

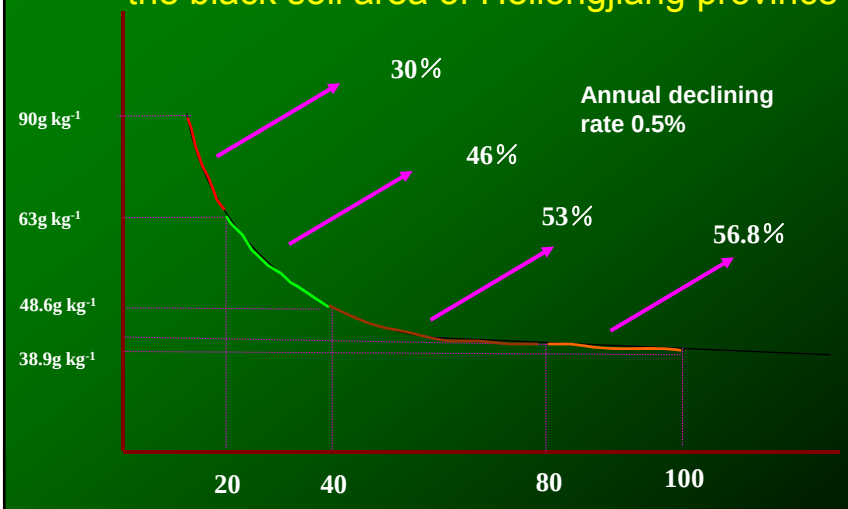
The latter corresponds to the release of approximately 380 ton $CO_2$ $ha^{-1}$ to the atmosphere.

The rapid reduction of SOC for the initial soil disturbance by cultivation and a relatively gradual loss later.


Soil Depth (cm)
0-17 (q)
18-32 (l)
33-43 (q)
Soil Bulk Density (g/cm3)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
14
50
Years of Cultivation


CEC (Cmol(+)/kg)
40
30
20
10
0
0
5
14
50
Years of Cultivation

## Soil organic carbon (SOC) after cultivation in the black soil area of Heilongjiang province




## *Impact on crop productivity*

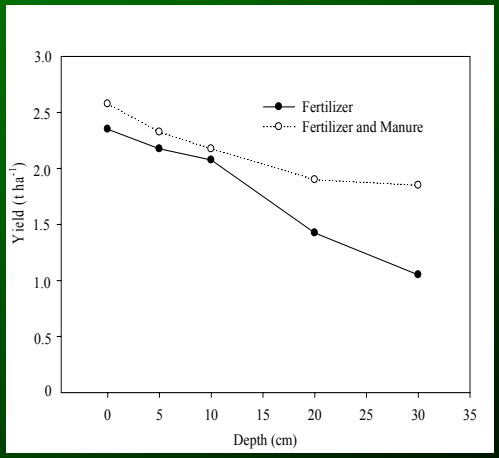
- Severity Yield kg/ha Soil thickness SOM%

| | | | |
|---|---|---|---|
| slight | 2625 | 30 cm | 3-4 |
| moderate | 1688 | 20 cm | 2-3 |
| severe | 1125 | 12 cm | 1-2 |

# *Impact on crop productivity*

- Soybean was reduced by 5.0%, 8.9%, 36.7%, 52.6% at the 5, 10, 20, and 30 cm topsoil removal rates.
- Significant yield reduction at 10, 20 and 30 cm topsoil removal
- No significant differences between non-eroded soil and 5 cm topsoil removal

  ----Sui et al, 2009




# Practices and strategies for soil erosion control

- *Basin tillage*
- *Contour tillage*
- *Rat tunnel tillage*
- *Conservation tillage*
- *Terraces and strip cultivation*
- *Fertilization and manure*
- *Government policies*

# Soil tillage

- Tillage operations control the soil environment by altering the soil geometry
  --- Alvare, C.Z. and R. Alvarez, 2000
- Ridge cultivation along the slope with less input results in

  --- destruction of granular particle structure
  --- soil compaction
  --- low water storage
  --- low surface hydraulic conductivity

# Basin tillage

- As early as 1940s, Chinese researchers had found the importance of basin tillage in reducing runoff and increasing crop yield.
- Applicable to farmlands with slope degree over 6°.
- The general practice is to build a block to form a basin within the furrow at a certain distance along the ridge during growing season.

# Basin tillage

- The determination of block distance is based on following equation:

  $L = 165.49\ \theta^{-0.47}$

  Where $L$ is the maximum block distance, cm; θ is the slope degree.
- The application of basin increased yield 16-20% in corn and 15-23% in soybean with average net income of 741-775RMB/ha

  -- Yang et al., 1994

# Contour tillage

- The simplest measure to control soil erosion by
  - -- reduce runoff
  - -- increase infiltration
  - -- reduce soil loss
- Best suitable for farmland with slope less than 10°

# Contour tillage

| Ridge direction | Slope steepness (degree) | Amount of runoff ($m^3/km^2.a$) | Amount of erosion (kg/ha.a) | Thickness of loss (cm/a) |
|---|---|---|---|---|
| Inclined | 7.3 | 72900 | 220 | 0.54 |
| Up-and-down | 4.8 | 143180 | 103 | 0.26 |
| Contour | 0 | 41340 | 5.57 | 0.01 |

# Contour tillage

| Ridge direction | Amount of runoff ($m^3/ha$) | Amount of sand loss | Total Nitrogen | Total Phosphorus ($P_2O_5$) | Total potassium ($K_2O$) | Organic matter |
|---|---|---|---|---|---|---|
| Up-and-down | 833 | 13 500 | 19.35 | 17.70 | 369.5 | 446.4 |
| contour | 699 | 9 000 | 14.70 | 10.95 | 255.6 | 324.9 |

# Conservation tillage

Two alternative approaches for local farmers in controlling soil erosion and enhancing crop yield.

√Reduced tillage with straw removal
----maintains the ridges and crop stubble from year to year, and uses deep-tillage in summer between the ridges to enhance water infiltration and hold much water.

√ No tillage
----entails cross-slope planting, and maintains crop residues on the surface through the winter.

# Conservation tillage

Annual average of surface runoff and sediment loss by different tillage

| Treatment | Runoff | Runoff Num. | Sediment loss | Sediment Loss Num | Coefficient |
|---|---|---|---|---|---|
| | mm | | t $km^{-2}$ | | % |
| No tillage | 3.7 | 9 | 23.2 | 5 | 0.78 |
| Reduce tillage | 48.5 | 14 | 2118.1 | 8 | 9.56 |
| Conventional tillage | 48.4 | 12 | 1357.2 | 11 | 9.9 |

# Conservation tillage

**Annual average of economic return under NT, RT and CT treatments from 2007 to 2009**

| Treatment | Crop | Yield | Input | Output | Benefit |
|---|---|---|---|---|---|
| | | Kg/ha | --------- RMB Yuan $ha^{-1}$ ------- | | |
| No tillage | Soy | 2466a | 1411 | 10425 | 9014a |
| Reduce tillage | Soy | 2103b | 1811 | 8509 | 6698b |
| Conv. tillage | Soy | 2143b | 2071 | 8797 | 6726b |
| No tillage | Corn | 9663a | 1721 | 10249 | 8528a |

# Terraces and strip cultivation

- Bench terraces have been used for a conservation measures in China for over 2000 years

## Terraces and strip cultivation

- The use of terraces in conserving soil erosion was only applied in the past 20 years in Northeast China.
- Beneficial effect of terrace

  --- reduced bulk density by 0.12g/cm$^3$

  --- increased total porosity by 2.0-2.9%

  --- infiltration rate of 0.4mm/min.

## Strip cultivation

- Soil is prepared for planting along narrow strips, with the intervening areas left undisturbed.
- Typically, 2-3 m of a perennial forage such as alfalfa and 5 m crop strip.
- Crop rotation is required and more effective.

## Problems for Terraces and strip cultivation

- The ecological and economic benefit of terrace cultivation and strip cultivation is strongly affected by slope degree and terrace width.
- The greater the slope the more labor needed, and the wider the terrace, the more soil removed.

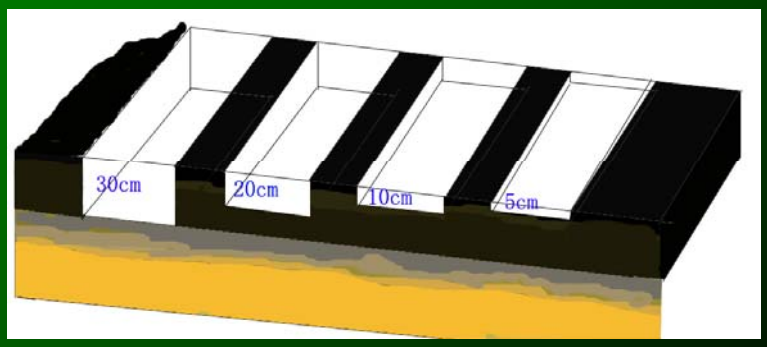
## A case study

Fertilization effects on crop productivity in eroded soil

- How does the black soil erosion and fertilization impact crop productions?
- No quantitative data were recorded in the area

# Experiment design

- O cm, 5 cm,10 cm,20 cm, 30 cm surface soil were removed.




# Experiment design

- 6° slope farmland in a typical Mollisols field
- Fertilizer application:
  --- NPK
  --- NPK + manure (15t/ha)
- Crop rotation
  --- Soybean
  --- Corn

## Soybean seedlings

## Corn growth at seedlings

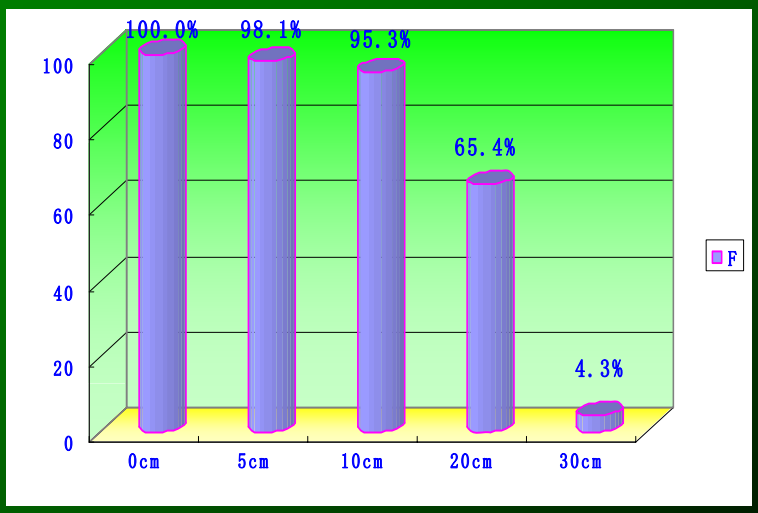
## Corn growth at tasselling

## Soybean growth

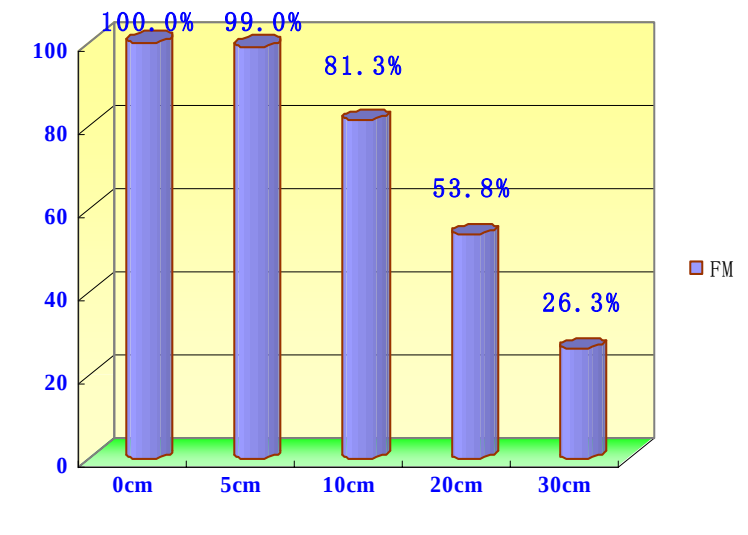
NPK

NPK＋manure

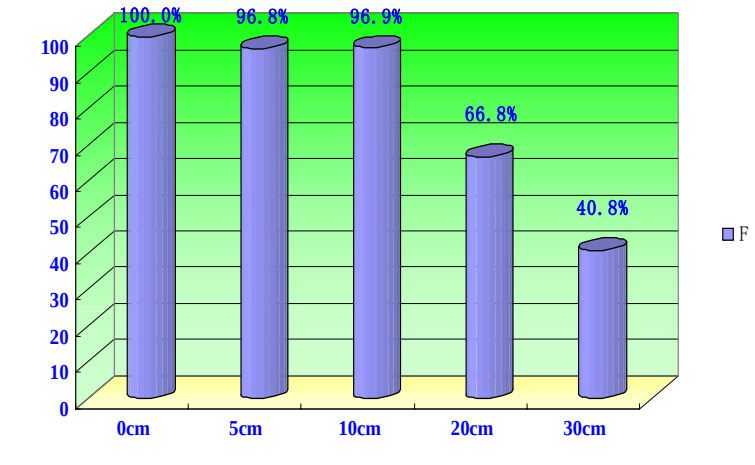
## Corn yield for NPK



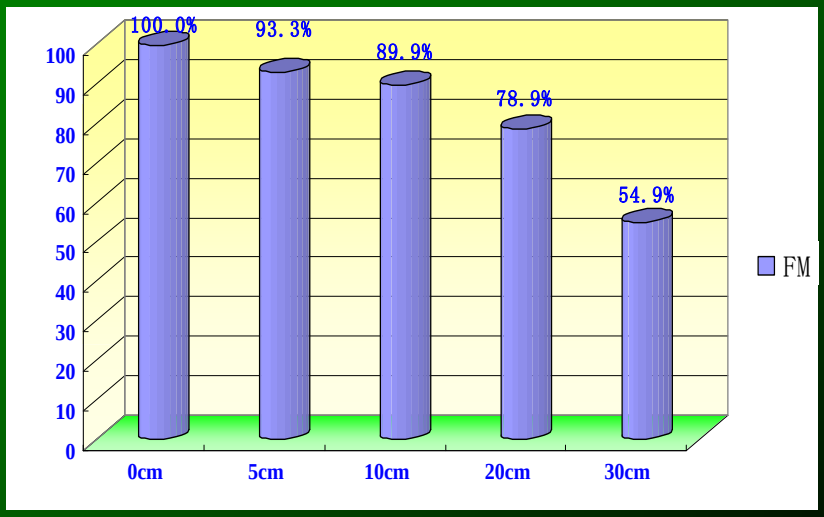
## Corn yield for NPK＋manure



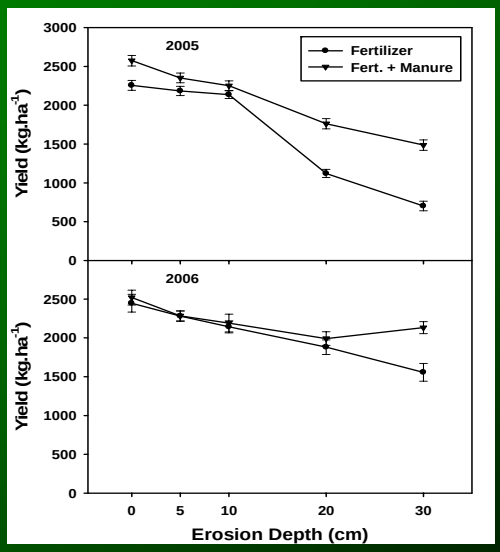

## Soybean yield for NPK



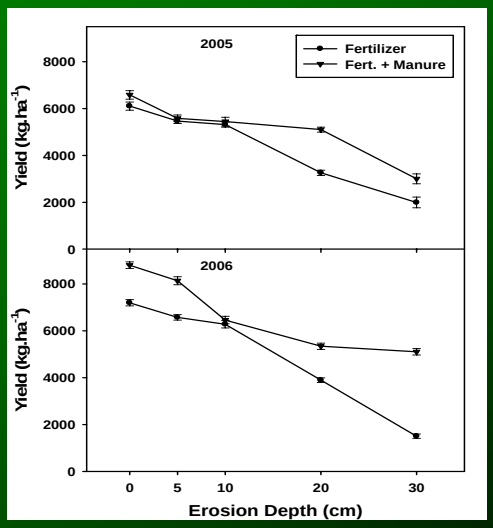
## Soybean yield for NPK + manure



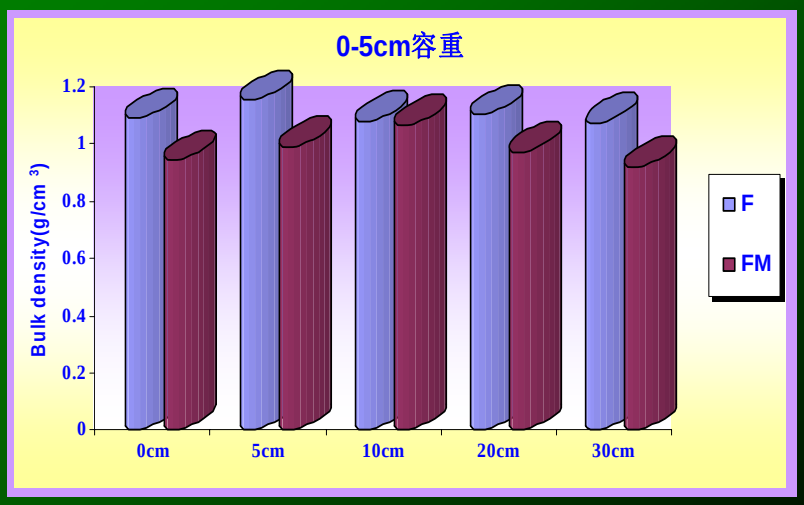

## Yield of soybean with soil removal



## Yield of corn with soil removal



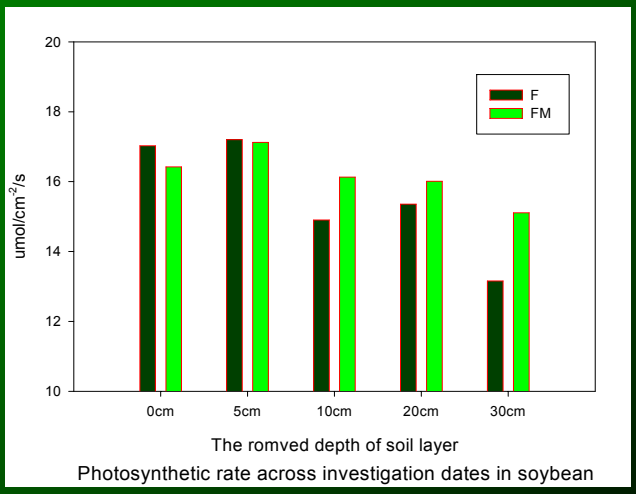

## Manure can reduce soil bulk density



•Photosynthetic rate decreased with dark layer thinning

•Manure application could increase photosynthetic rate

Soybean

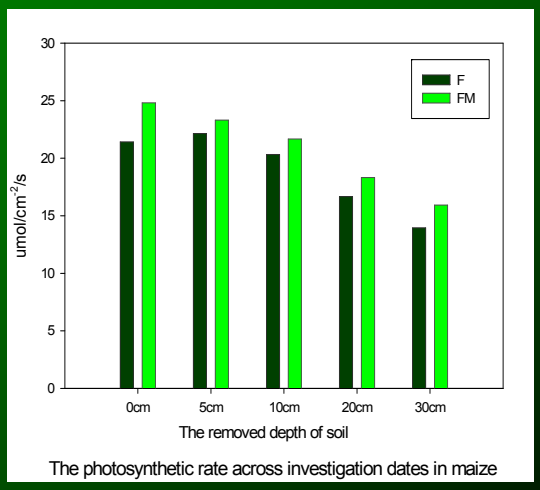



Photosynthetic rate across investigation dates in soybean

•Photosynthetic rate decreased with dark layer thinning

•Manure application could increase photosynthetic rate

Corn




The photosynthetic rate across investigation dates in maize

## Removal effect on crop yield

- Yield was substantially reduced by deep topsoil removal.
- Corn was more sensitive to erosion than soybean.
- Addition of cattle manure could compensate the yield loss by erosion to a certain extent.

## Government policies

The successful implementation of soil conservation measures is only possible through a combination of scientific, socio-economic and political considerations.

---- Morgan, 2005

## Programs and investment

- ★ 2004, Water Resource in Northeast China.
- ★ 2005, Investigation on Soil Erosion and Ecological Security in China
- ★ 1.1 billion RMB Yuan by mechanical approaches before 2008
- ★ 426 million RMB Yuan to improve slope farmland since 2008 to 2010
- ★ 0.7 billion RMB to control soil erosion in watershed scale starting this year

## Government policies

- **National Soil and Water Conservation law only prohibits slope land over 25° to be reclaimed, and those under cultivation should be transformed into forest.**
- **Since farmlands under different slope degree need corresponding conservation measure, definite stipulation for land users to legally manage slope farmland needs enacted.**

## Government policies

- Economic compensation mechanism for eroded soils should be established, i.e. if farmers adopt soil control practices the government should provide payment.
- Subsidies such as terrace construction, ridge direction change, seeds for plant strip, labor resources should directly go to land users' hand.

## Summary

- Northeast China is the bread basket of China
- 1/3 of China commodity grain is from the region
- Commodity percentage 60%
- Feed 216 million urban residents annually

## Summary

- Soil erosion is characterized as
  --- water erosion
  increase in Hei-long-jiang not in Ji-lin and Liao-ning Province
  --- losses of top soil layer
  --- decline in soil organic matter
  --- reduction in soil biological activities

## Summary

- Soil erosion accounts for 17.2% of the total area
- Hei-long-jiang has the most eroded area
- Average annual declining rate of SOM is 0.5%

## Summary

- Increased bulk density, reduced field water capacity and infiltration rates are the main physical properties deteriorated in eroded soils
- Increased fungi and decreased bacteria and actinomyces as well as the soil enzymes activities are the main biological characteristics

## Summary

- Cultivation reduced soil organic carbon content, led to decline of CEC and increased soil compaction.
- SOC declined sharply with a few years of cultivation and then slowly afterwards.

## Summary

- Bench terraces reduced bulk density, increased total porosity and infiltration rates.
- Contour and basin tillage is the simplest measure to control soil erosion.
- Government polices and subsidies are urgently needed.

## Summary

Crop rotations with

- minimum tillage
- additions of manure and chemical fertilizers
- or addition of wheat straw

Could be a viable method of

- Maintaining SOC content
- Improving crop productivity in eroded soils

# Acknowledgements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