Effects, Present Problems and Countermeasures of Conservation Tillage in the Loess Plateau of China

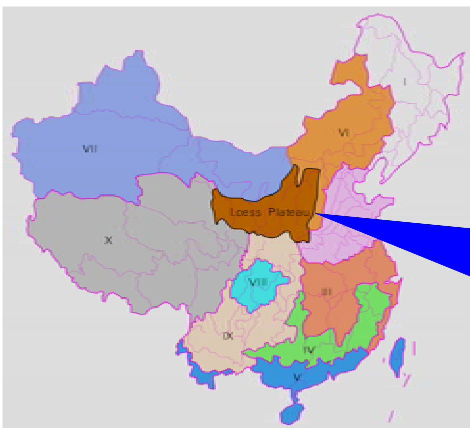
Prof. *Huang Gao-bao*

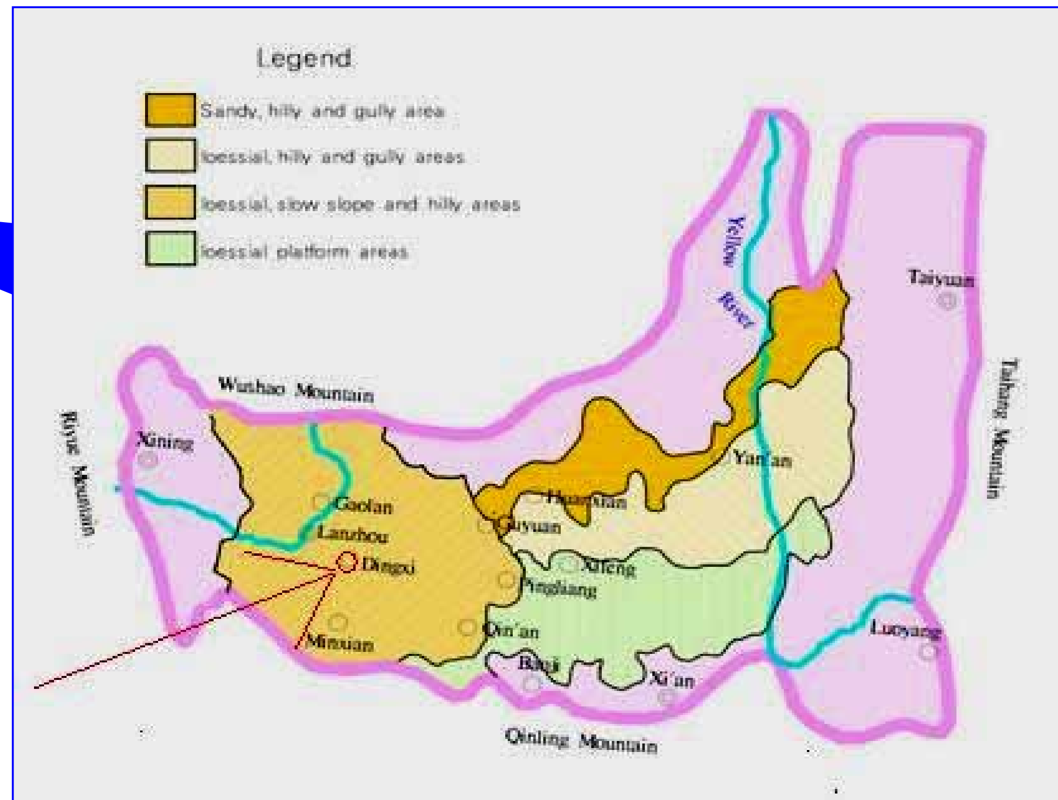
Gansu Agricultural University

OUTLINE

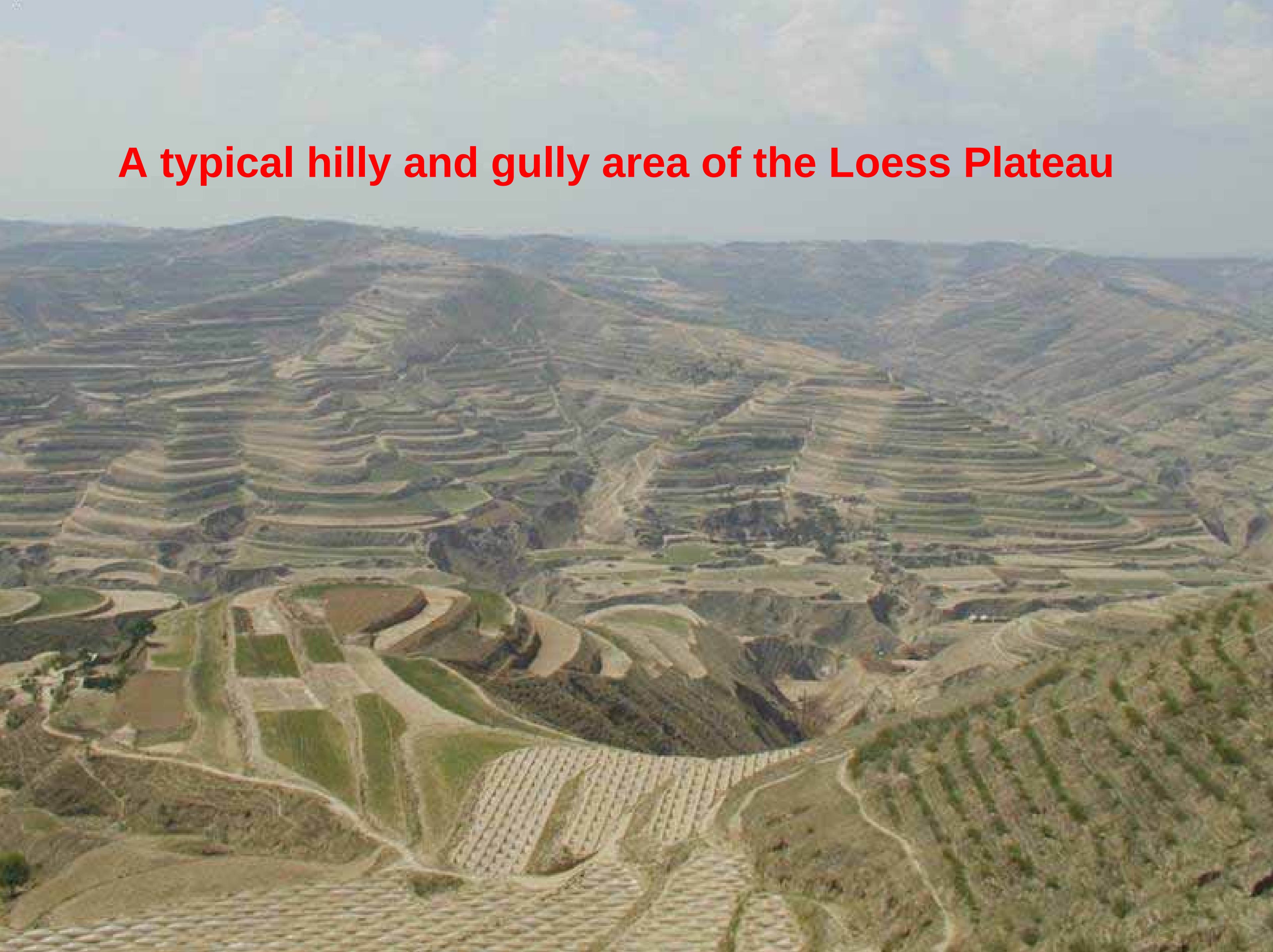
- Background of the Loess Plateau of China
- Integrated effects of conservation tillage in the Loess Plateau of China
- Present problems in the development of conservation tillage in the Loess Plateau of China
- Countermeasures and proposals in the development of conservation tillage in the Loess Plateau of China

Background





Soil erosion and limited water available are two major constraints


A typical hilly and gully area of the Loess Plateau

Background

- Erodible topsoil and severe soil erosion
  - Annual erosion soil add up to 2.1billion ton
  - Erosion area reach to $3.4 \times 10^5 km^2$
  - Erosion intensity even over $20000 t/km^2 \cdot a$
- Poor vegetation
  - Forest cover rate only 6.5%
  - Vegetation cover rate of grassland 25%～65%
  - Grassland with medium and the worst degradation make up to 68.8%

Background

- Lack of water resource
  - Water resource 440m^3 per capita and 2800m^3/ha
- High rainfall variability
- Mono-agricultural structure and poor management
- Low and unstable yield
- Low income of farmers

Previous research

- 1960s, mainly focused on gravel mulch
- 1970s, started minimum tillage
- 1980s, focused on plastic and straw mulch
- 1990s, combined minimum tillage with straw mulch
- 2001, conducted conservation tillage

Background

- Many reports have shown that conservation tillage positively affects soil quality and crop yield
- However, contradictory results were also reported:
  - Lower temperature may slow germination of crop
  - Increased weeds, insect and rodent pest
  - Reduce yield in early stage

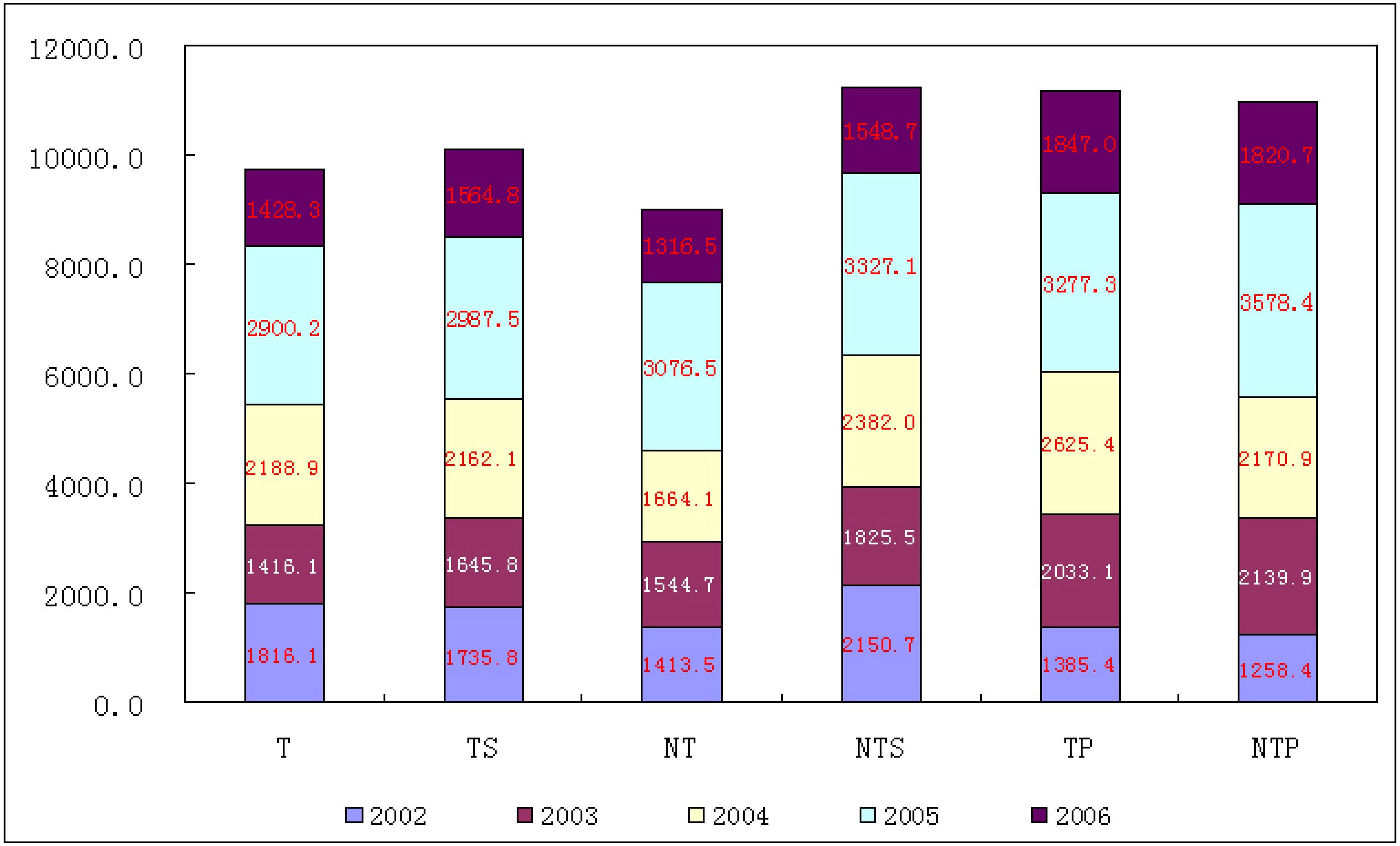
Background

- Therefore, The Australian Centre for International Agricultural Research (ACIAR) project “improving the productivity and sustainability of rain-fed farming systems for the western Loess Plateau of Gansu province” has been implemented in Dingxi, Gansu since 2001.
- The aim of the research is to identify a suitable conservation agriculture practice for the western loess plateau.

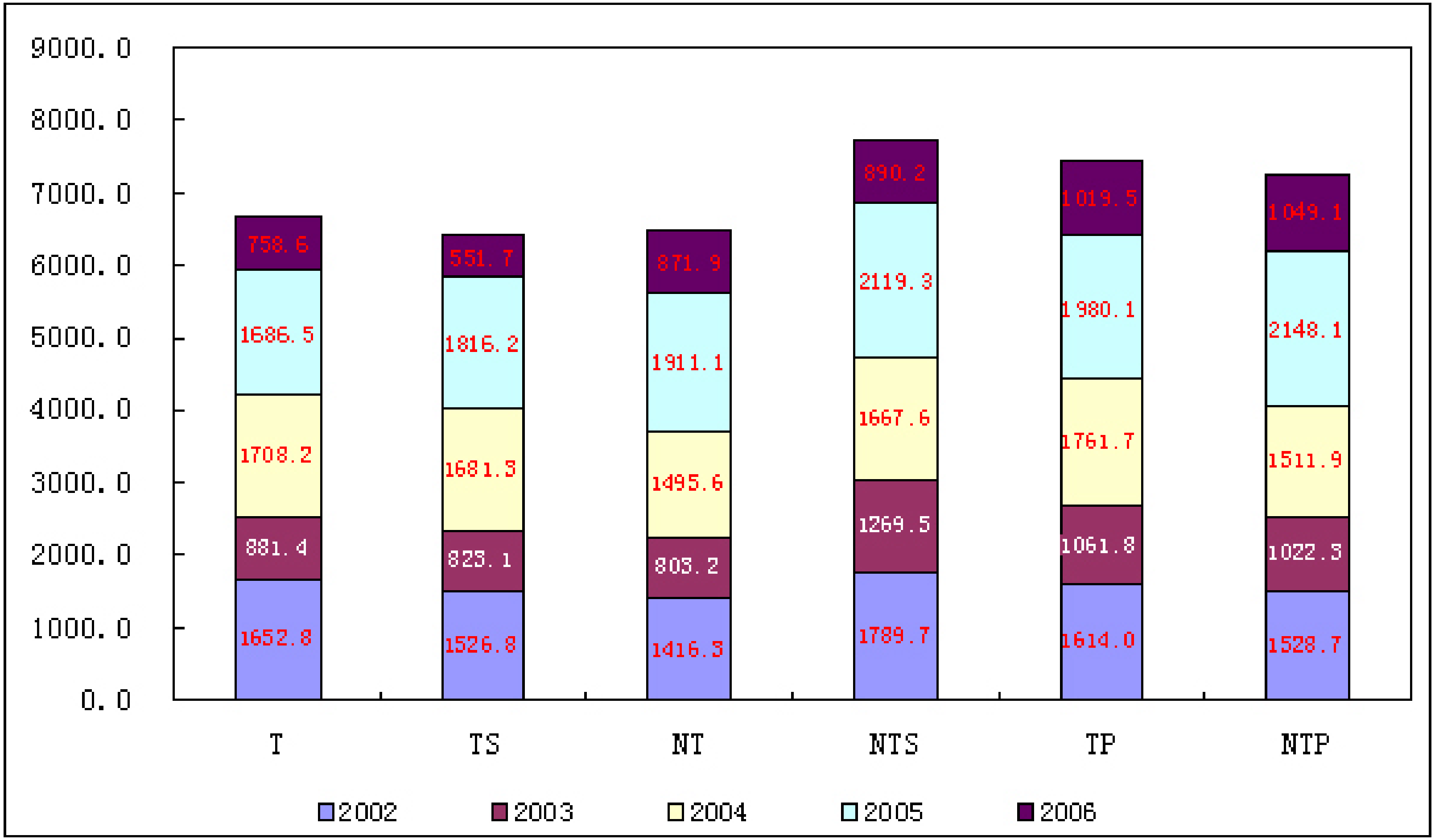
The details of the treatments designed in the long-term conservation tillage experiment in Dingxi, Gansu

Code	Treatments
T	Conventional tillage with no straw
TS	Conventional tillage with straw incorporated
NT	No-till with no straw cover
NTS	No-till with straw cover
TP	Conventional tillage with plastic mulch
NTP	No-till with plastic mulch

Impacts of different tillage and stubble management on grain yield _ Spring wheat



Impacts of different tillage and stubble management on grain yield _ Field pea



Summary

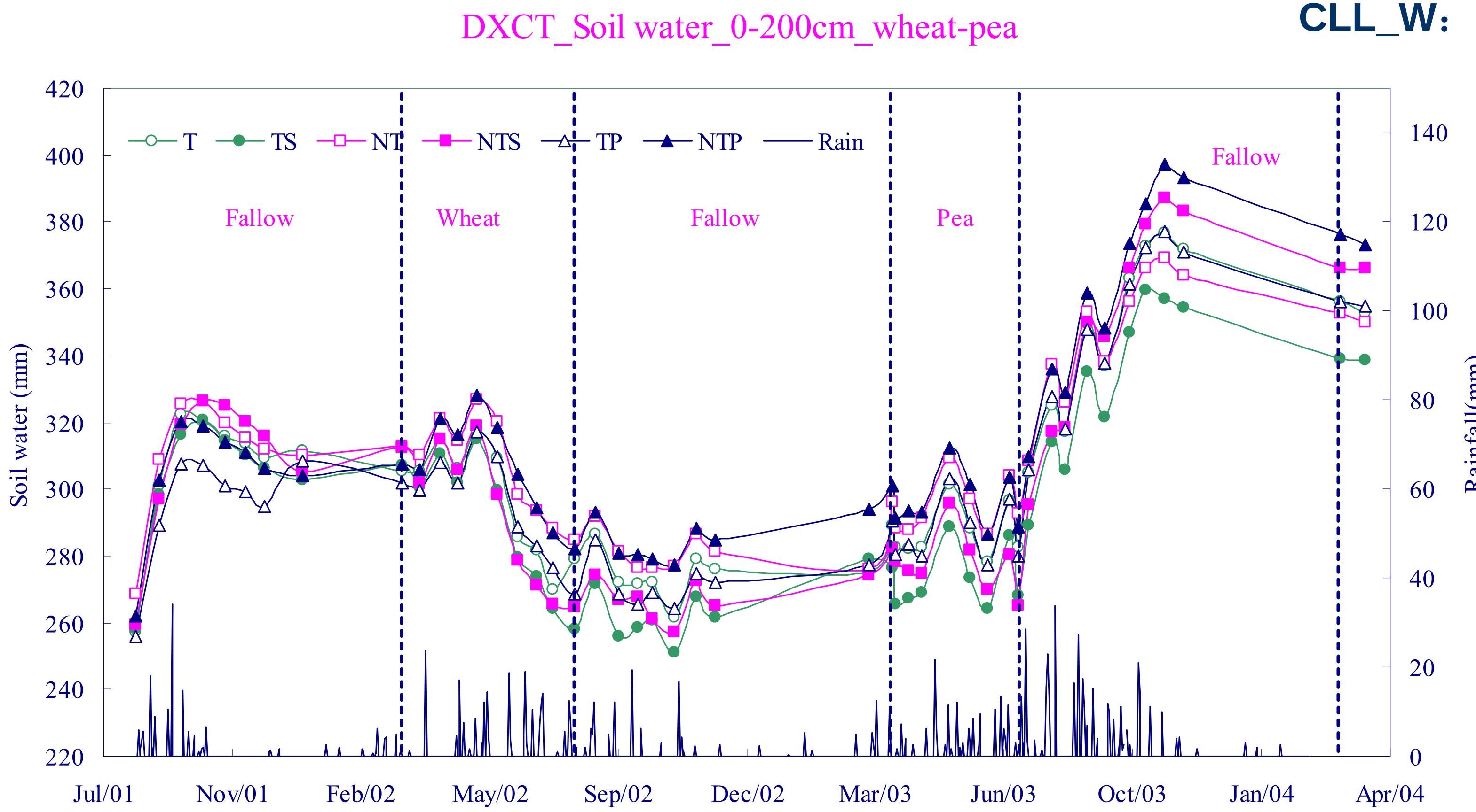
- Grain yield
  - Overall, NTS produced the highest average yield for both wheat and field peas over five seasons
  - Although both plastic mulch treatments had similar yields as NTS for spring wheat, these two treatments are unsustainable
  - Grain yield from no-till without straw was un-satisfactory

Soil moisture dynamics

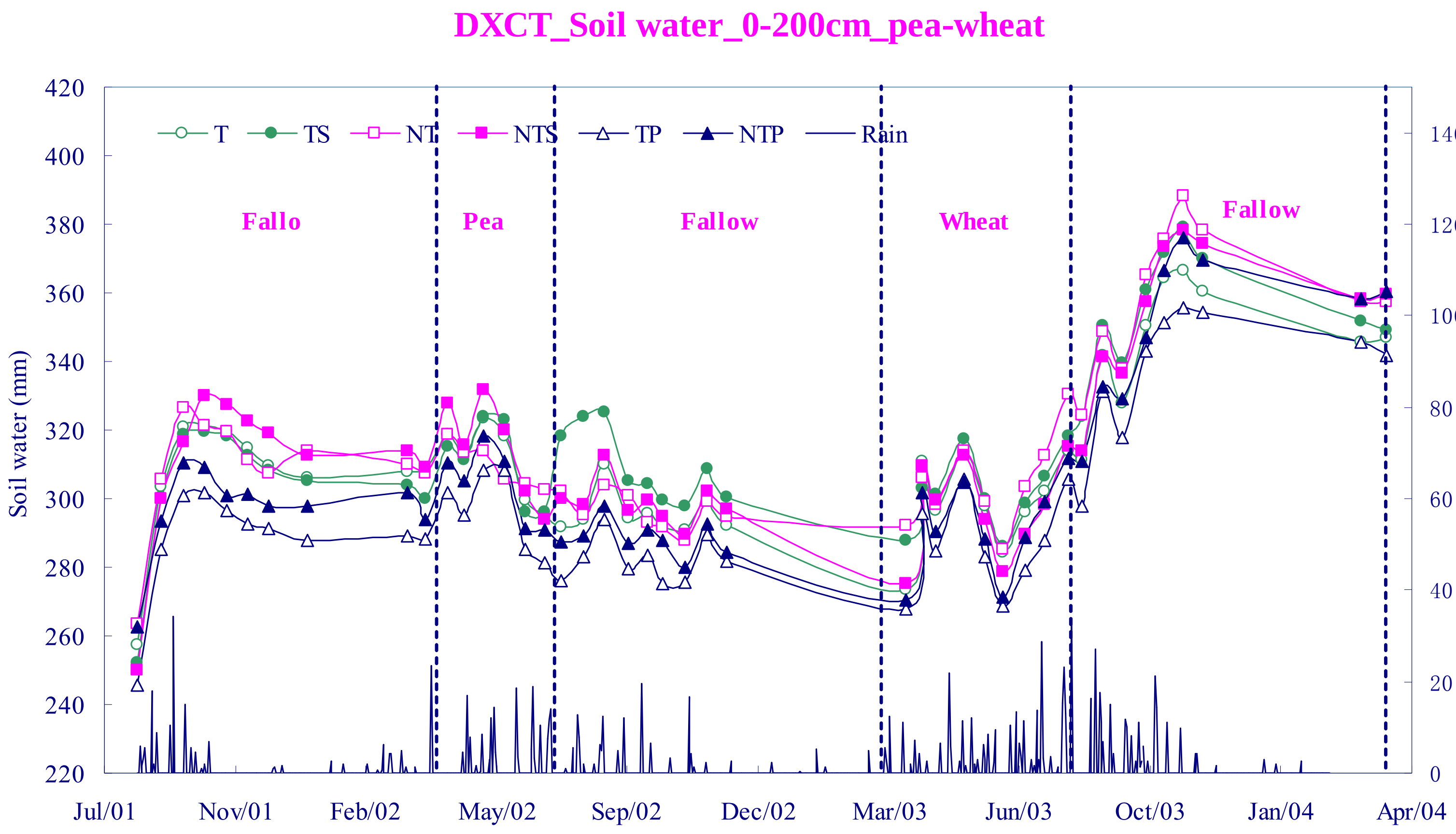
DUL:554

CLL_P：235

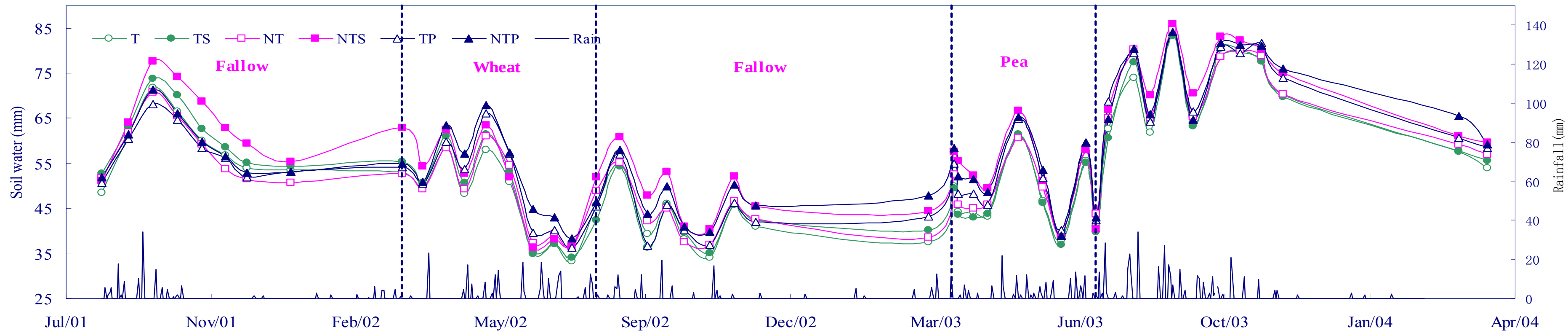
CLL_W：179



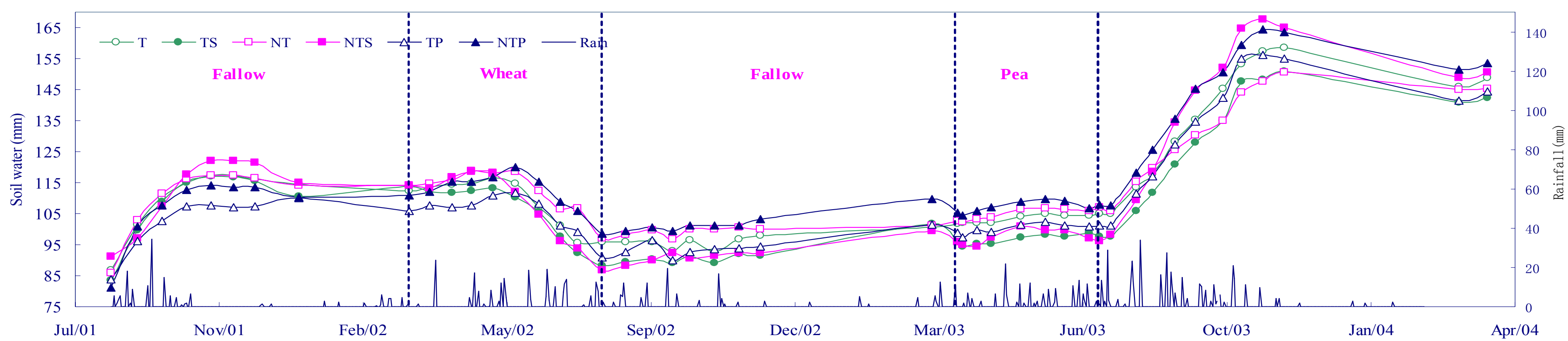
Soil moisture dynamics



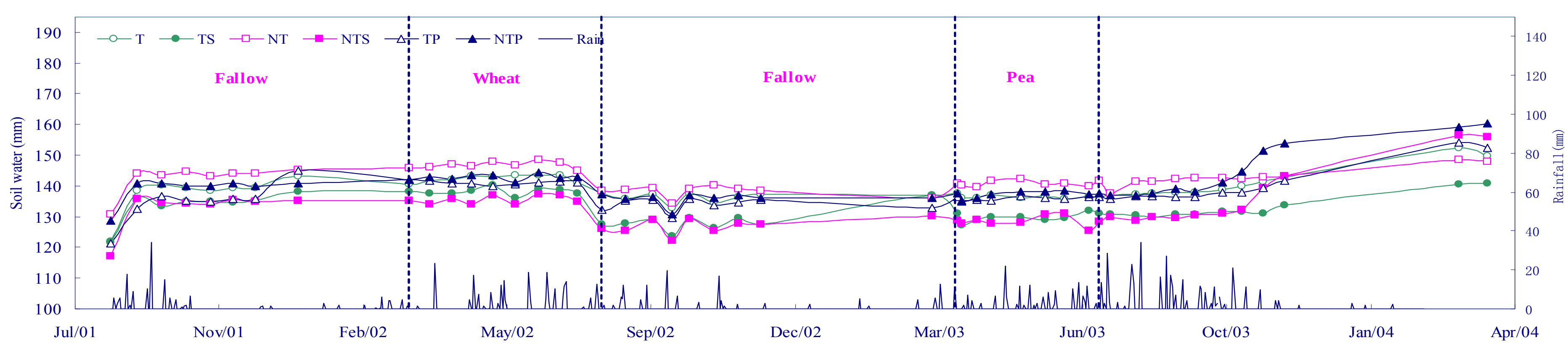
DXCT_Soil water_0-30cm_wheat-pea

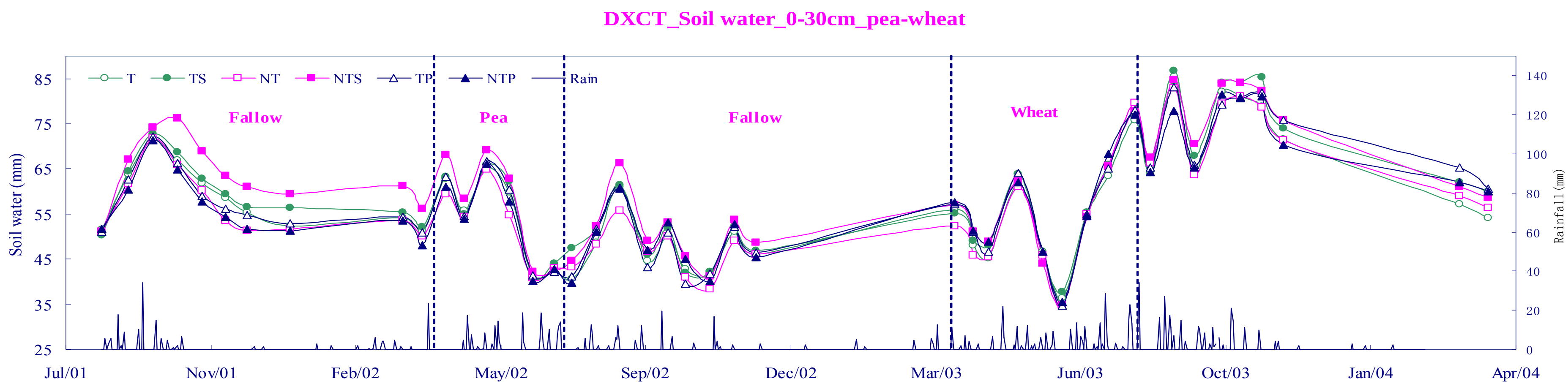


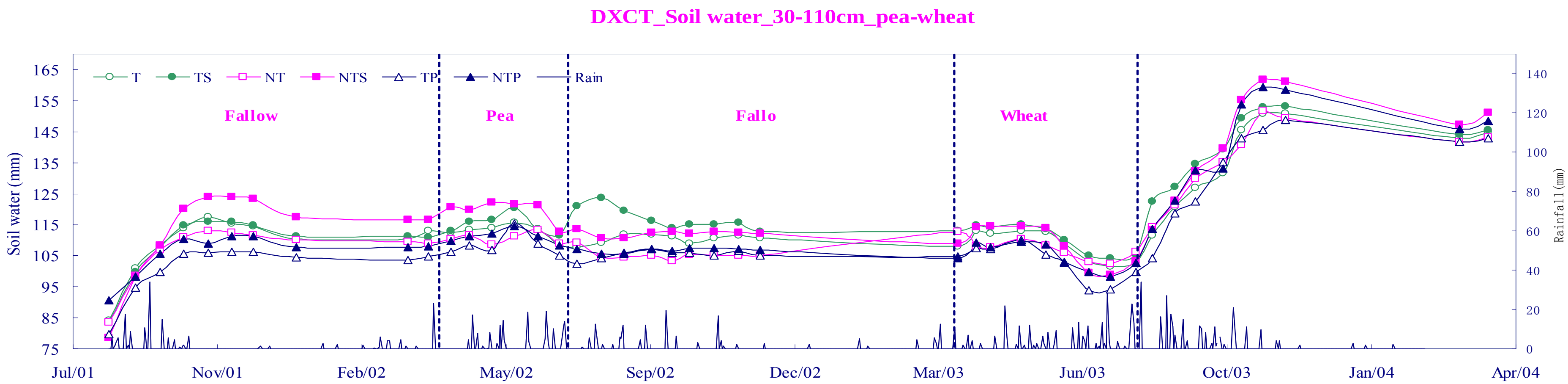
DXCT_Soil water_30-110cm_wheat-pea

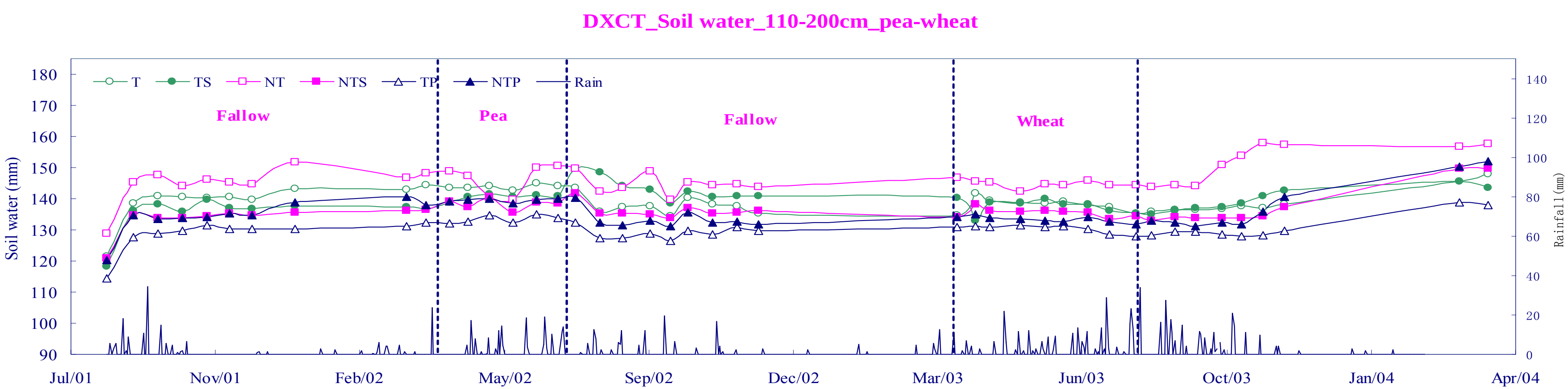


DXCT_Soil water_110-200cm_wheat-pea

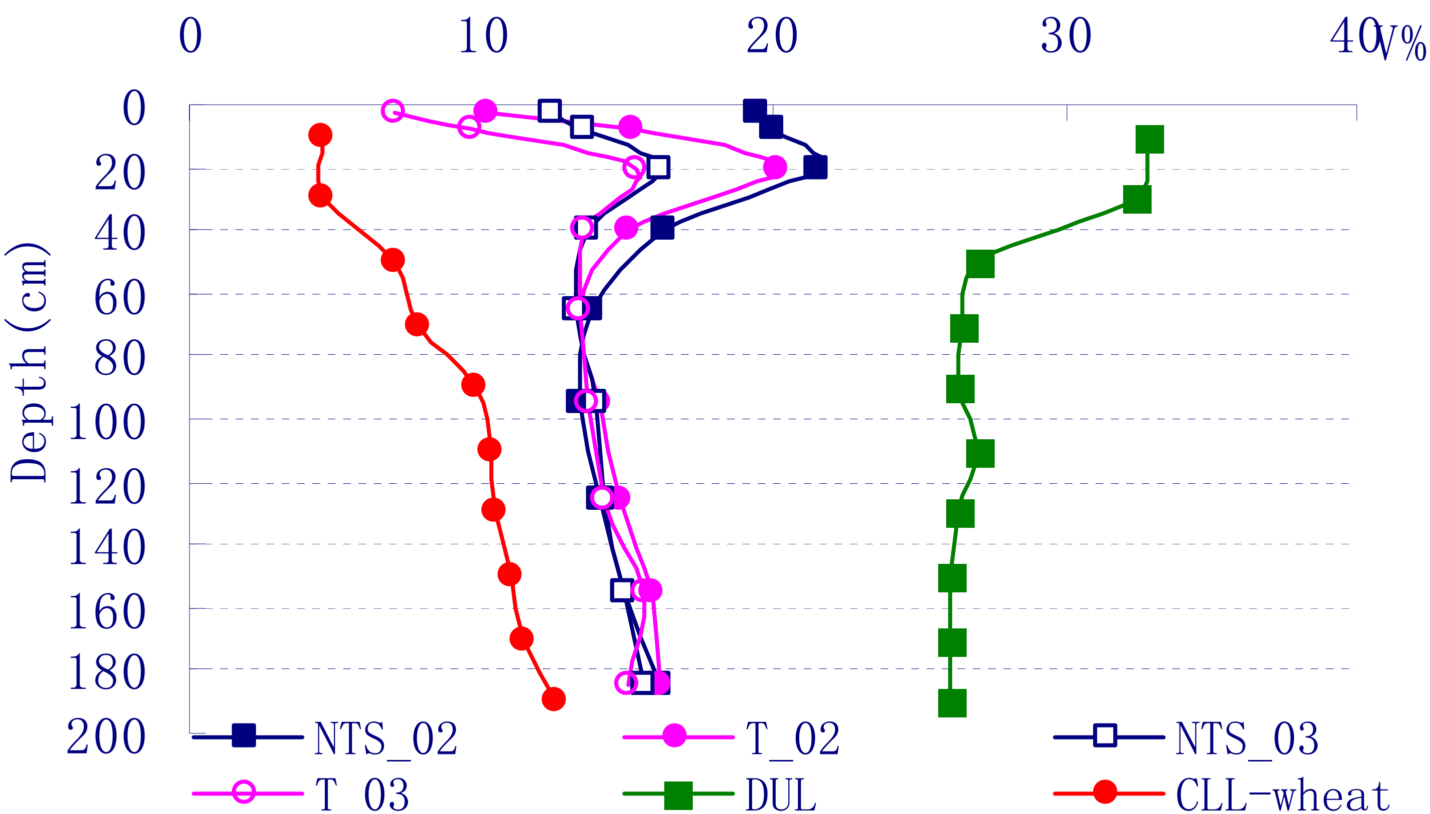



DXCT_Soil water_0-30cm_pea-wheat
T
TS
NT
NTS
TP
NTP
Rain
Fallow
Pea
Fallow
Wheat
Soil water (mm)
Rainfall (mm)
Jul/01
Nov/01
Feb/02
May/02
Sep/02
Dec/02
Mar/03
Jun/03
Oct/03
Jan/04
Apr/04

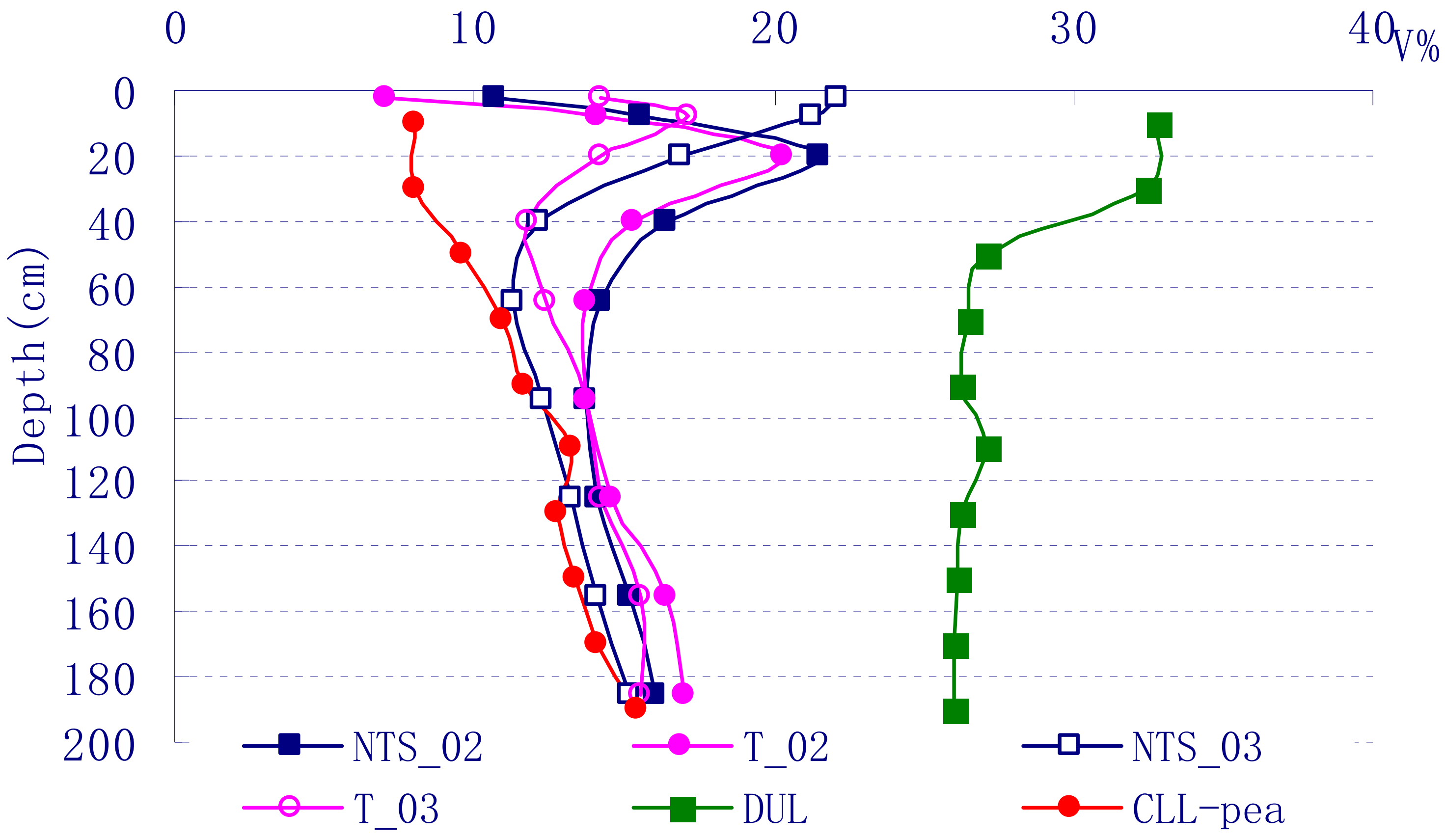

DXCT_Soil water_30-110cm_pea-wheat
T
TS
NT
NTS
TP
NTP
Rain
Fallow
Pea
Fallo
Wheat
Soil water (mm)
Rainfall (mm)
Jul/01
Nov/01
Feb/02
May/02
Sep/02
Dec/02
Mar/03
Jun/03
Oct/03
Jan/04
Apr/04


DXCT_Soil water_110-200cm_pea-wheat
T
TS
NT
NTS
TP
NTP
Rain
Fallow
Pea
Fallow
Wheat
Soil water (mm)
Rainfall (mm)
Jul/01
Nov/01
Feb/02
May/02
Sep/02
Dec/02
Mar/03
Jun/03
Oct/03
Jan/04
Apr/04

Soil water at sowing (wheat)



Soil water at sowing (pea)

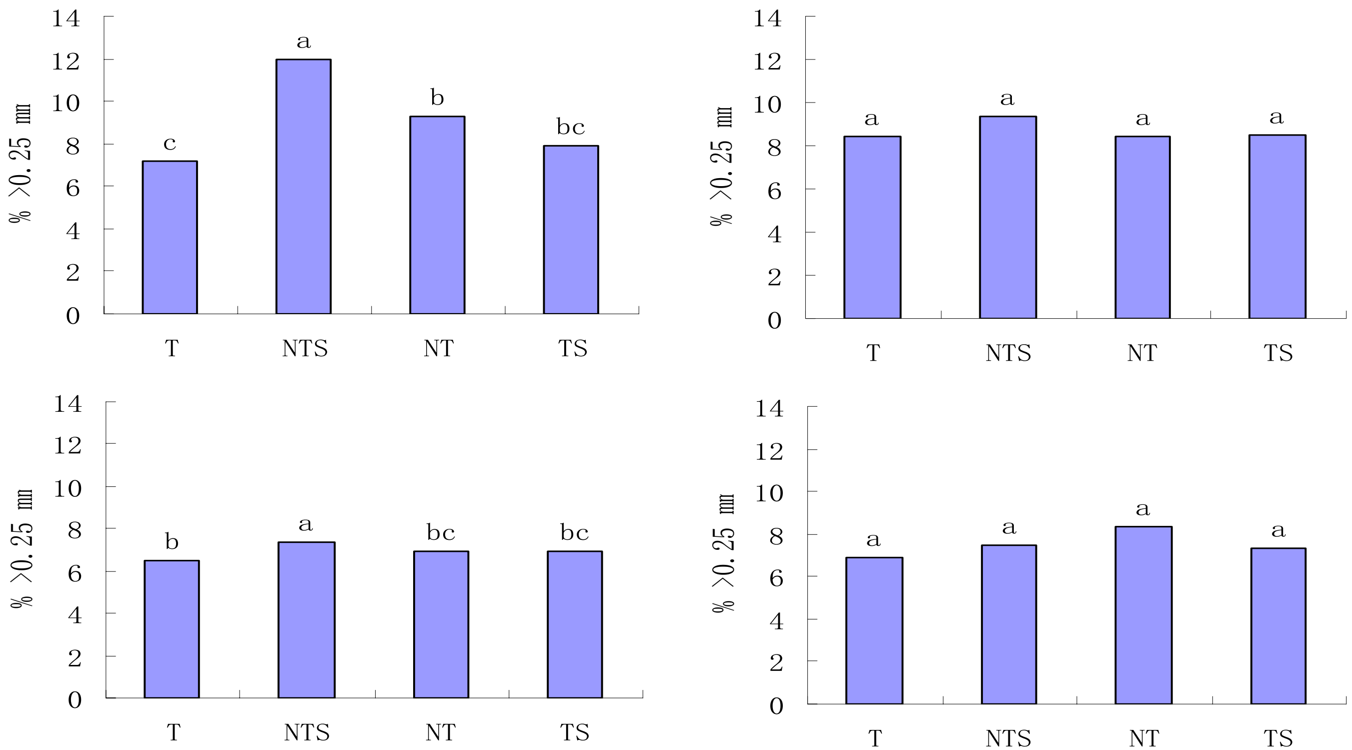


Summary

- Soil water
  - Seasonal variation was large and treatment differences were small
  - NTS treatment had more water available to crops probably due to greater infiltration and less evaporation
  - Soil moisture profiles never being filled up during the past 5 years

Water stable macro-aggregation

measured in Aug, 2003 after harvest



0-5cm

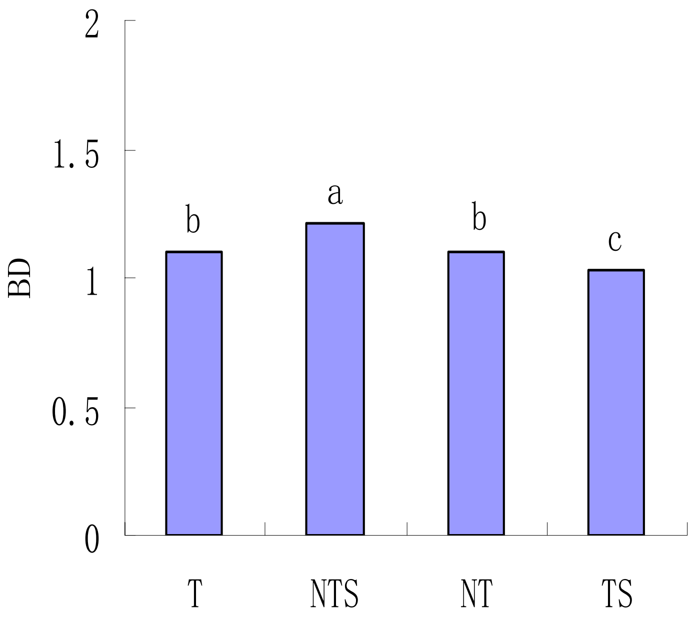
5-10cm

W/P

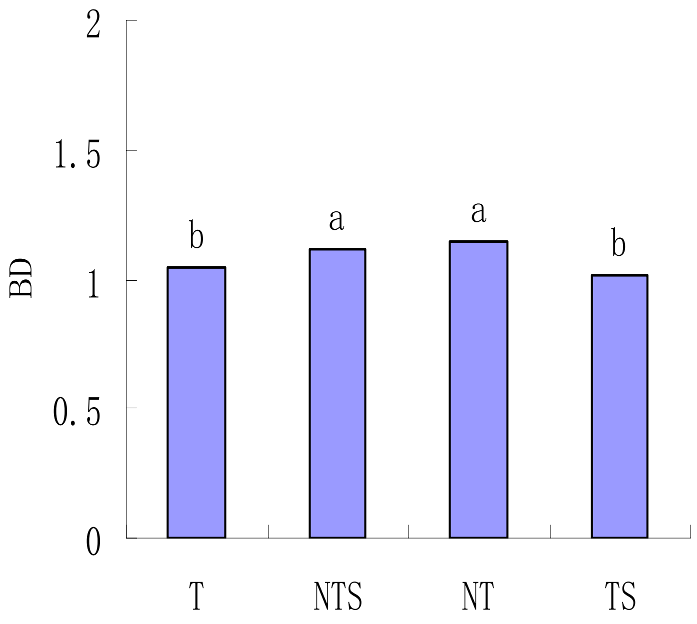
P/W

Soil bulk density

measured in Mar. 2004, before sowing



W/P



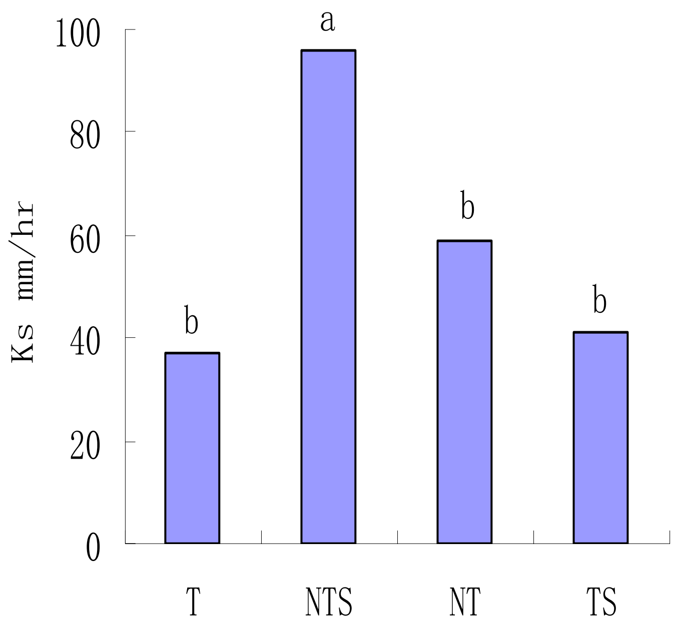
P/W

TOC and C_{WB10}- modified Walky-Black using 12*N* H_2SO_4

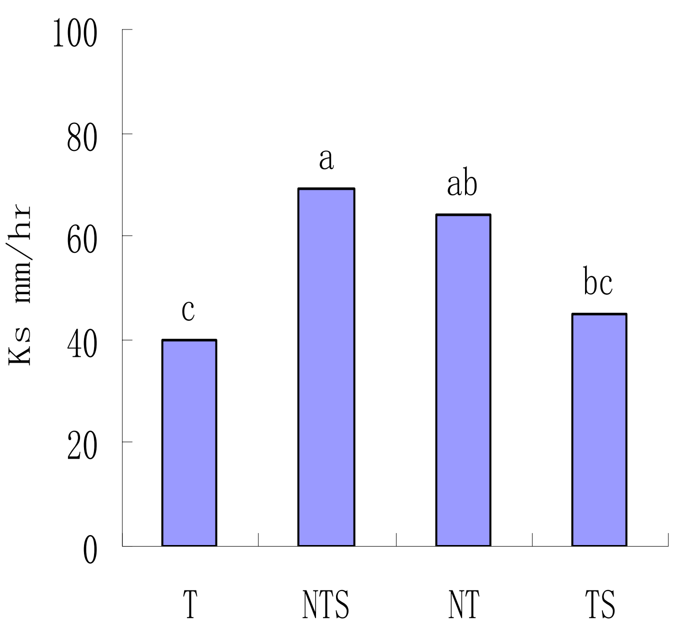
treatment		TOC $g\ kg^{-1}$		C_{WB10} $g\ kg^{-1}$	
		0-5cm	5-10cm	0-5cm	5-10cm
W/P	T	8.30C（100）	7.91B（100）	4.53C（100）	4.52A（100）
	NTS	9.86A（119）	8.98A（114）	5.65A（125）	4.93A（109）
	NT	8.83BC（109）	8.27B（104）	4.82BC（106）	4.81A（106）
	TS	9.04B（106）	8.93A（113）	4.97B（115）	5.08A（113）
P/W	T	8.64A（100）	8.46A（100）	4.67A（100）	4.75A（100）
	NTS	9.00A（104）	8.73A（103）	5.21A（112）	4.62A（97）
	NT	8.58A（99）	8.44A（100）	4.84A（104）	4.84A（102）
	TS	8.91A（103）	8.58A（101）	5.13A（110）	5.11A（107）

Saturated hydraulic conductivity

measured in Mar. 2004, using disc permeameter



W/P



P/W

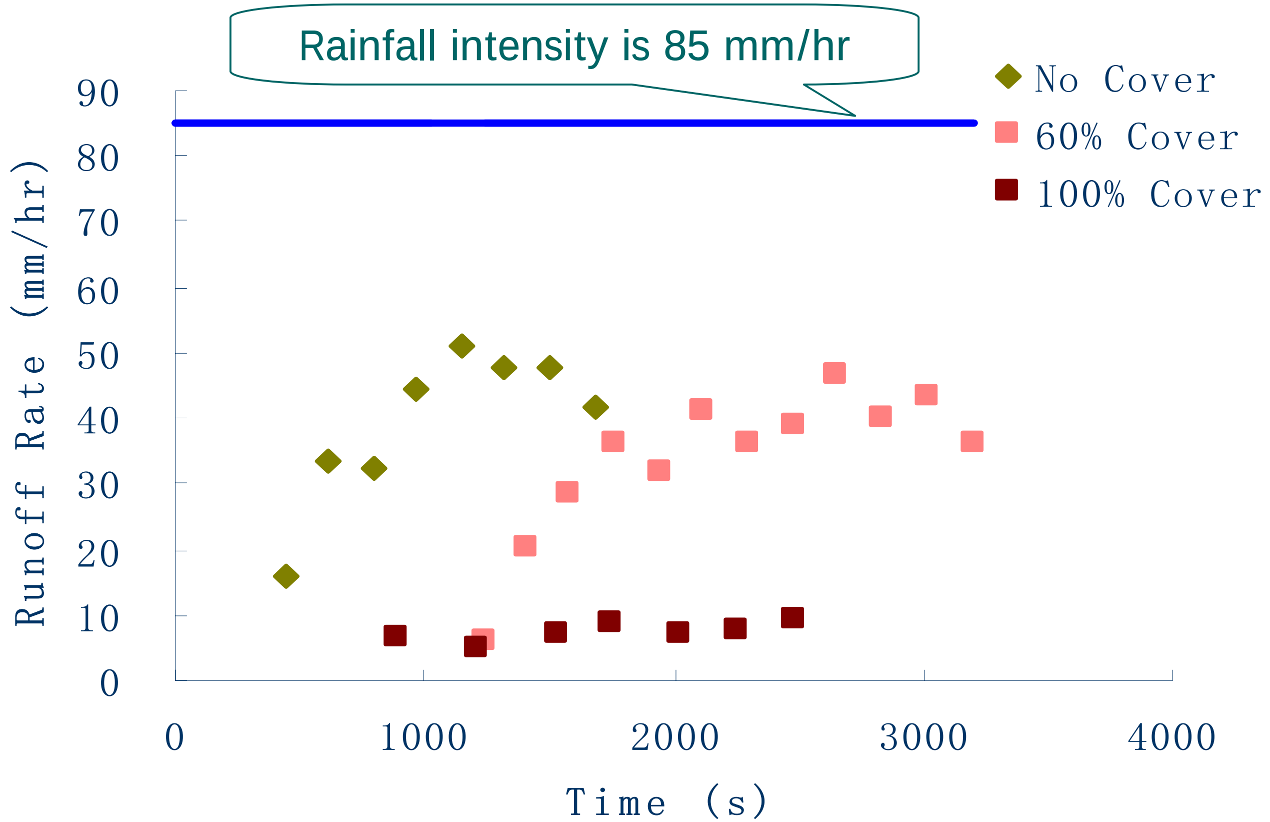
Summary

- Soil quality
  - NTS increased soil organic carbon and had greater proportion of water stable macro-aggregation
  - This indicates that the soil structure became more stable in NTS

Summary

- Soil quality
  - Saturated hydraulic conductivity on NTS was significantly higher than other treatments in both phases
  - This confirmed that NTS had the greatest infiltration rate

Effects of conservation tillage on Soil Anti-erodibility



Effects of conservation tillage on Soil Anti-erodibility

Rotation Sequence	Treatment	Ponding start time(min)	Runoff start time(min)
P→W→P→W→P	NT	7.33b	8.04c
	NTS	8.75a	9.21a
	T	5.30c	5.38d
	TS	7.79b	8.38b
W→P→W→P→W	NT	6.84b	7.5ab
	NTS	8.67a	9.17a
	T	6.12b	7.01b
	TS	7.13b	7.79ab

Effects of conservation tillage on Soil Anti-erodibility

Rotation Sequence	Treatment	Sum Runoff（mm）	Sum infiltration（mm）	Sum erosion（g/m^2）
P→W→P→W→P	NT	45.89b	39.11a	28.02b
	NTS	44.78b	40.22a	26.57b
	T	60.32a	24.68b	70.8a
	TS	50.23b	34.77a	32.11b
W→P→W→P→W	NT	62.90a	22.10b	32.73a
	NTS	44.85c	40.15a	14.89c
	T	53.10b	31.90b	27.77ab
	TS	66.26a	18.74c	23.79b

Summary

- slow down runoff start time by 2.16～3.83min
- reduce runoff by 18.4％～34.7％
- increase infiltration by 20.5％～38.6％
- reduce soil erosion by 86.5％～166％

Effects of conservation tillage on economic benefit

Crop	Target variable	Treatment[1]					
		T	TS	NT	NTS	TP	NTP
Spring wheat	output（￥/hm²)	2912	2985	2690	3390	3262	3200
	input（￥/hm²）	2360	2890	1445	1970	3145	2225
	ratio of output and input	1.234	1.033	1.862	1.721	1.037	1.438
	Net return（￥/hm²）	552	95	1245	1420	117	975
	Economic profit rate（%）	23.4	3.3	86.2	71.2	3.7	43.8
Field pea	output（￥/hm²)	2519	2525	2350	2951	2762	2638
	input（￥/hm²）	2179	2614	1259	1694	2959	2039
	ratio of output and input	1.156	0.966	1.867	1.742	0.933	1.294
	Net return（￥/hm²）	340	-89	1091	1257	-197	59
	Economic profit rate（%）	15.6	12.0	86.7	121.2	-6.7	29.4

Summary

- Improve the ratio of output and input by 39.47%
- increase net return by 900￥/hm^2

Harmonious management of organism mulching and stubble covering on bare field in an area supposed to be poor in straw

- Lower temperature of covered soil slow germination
- Stubble allelochemicals inhibit weeds as well as crops
- Increase perennial weeds , diseases, insect and pest
- Not conducive to manure application

Development in combining legume-cereal -potato crop rotations with zero tillage and stubble retention

- Potato stubble is too less to meet requirements of conservation tillage that maintains at least 30% crop residue on the soil surface
- Soil environment of no-till is unfavorable to potato growth.

Improvement of mechanization and semi-mechanization technologies to match with sloping land

It is difficult to adopt large conservation tillage machine in the loess plateau, because:

- sloping farmland with a degree above 5 in western Loess Plateau account for 80% of total farmland
- Farmland is dominated by a number of small-scale productions and decentralized management of households in western Loess Plateau

Small and Medium-sized equipments for zone tillage need to be developed

- Not only to achieve five functions at one operation, including
  - Opening a furrow
  - No-till planting
  - Fertilizing
  - Covering soil
  - Pressing
- But also to accommodate other farm system issues, such as
  - Breaking up compacted layers
  - Fertilizing and seeding separately
  - Preventing the residue from blocking
  - Profile modeling for sloping land
  - incorporation of animal manures

Ingrained traditional ideas of farmers

- Certain perennial weeds and certain diseases can become problematic
- Crop residues on the soil surface were considered a barrier to good seed germination
- Regardless of eco-environment, tillage systems need to be selected that will contribute to sustain farm profitability

Acquiring aid in the form of policies and capital from government

Policies:

- Work out feasible plans, and form a popularization system
- Teach theories and experiences to farmers by technical training
- Organize agricultural extension events
- Provides the necessary guidance

Acquiring aid in the form of policies and capital from government

Capital :

- Earmark large amounts of funds to research and develop supporting agricultural machinery
- Implement policy of fiscal subsidies, to encourage farmers to apply conservation tillage

Developing conservation tillage into conservation agriculture by system designing

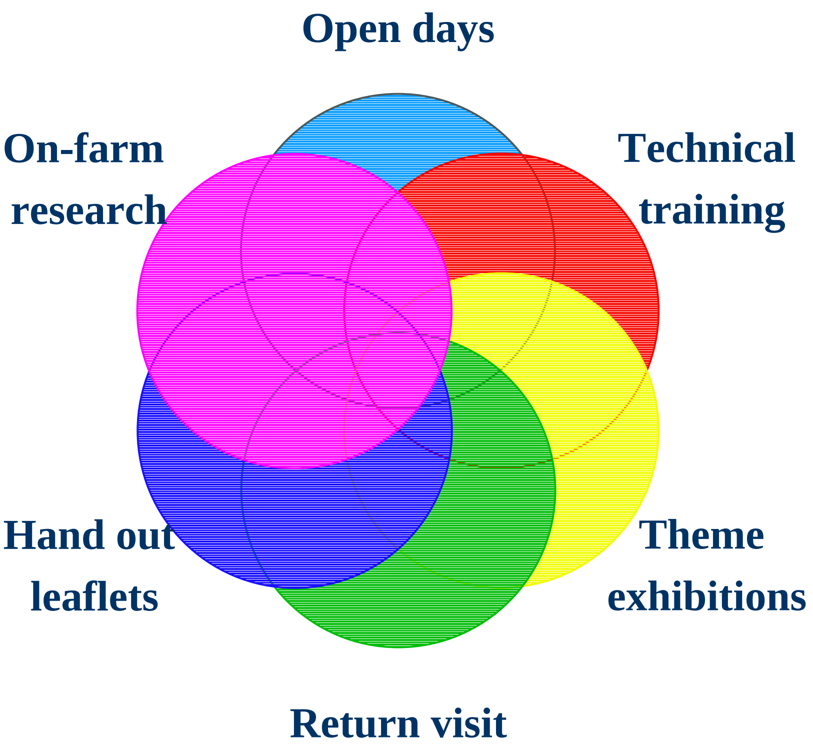
- Altering tillage practices is only part of soil conservation management. Erosion can also be reduced by changing cropping systems
- For example, including forage crops in rotations reduces tillage requirements and also contributes to rebuilding soil structure and organic matter levels

Speeding the progress of research and development of supporting agricultural machinery

- Large machine practiced by large-scale, commercial farmers worldwide is not suitable for small-scale and decentralized household.
- Scientific research personnel create appropriate set of machinery easily operated with high efficiency, satisfying the diverse requirements of sloping land

Intensifying publicity and training for farmers

Setups for popularizing agricultural techniques and units of agricultural scientific research should popularize conservation tillage technology by conducting several activities



Establishing conservation tillage technology demonstration zones

- These zones play their role in demonstration projects and driving force
- So as to bring along and promote the development of other areas, inducing the close combination and coordinated development of ecological improvement, economic construction and social development.


Thank YOU