Soil Water Depletion and Soil Erosion In the Coarse Soil Region of the Loess Plateau

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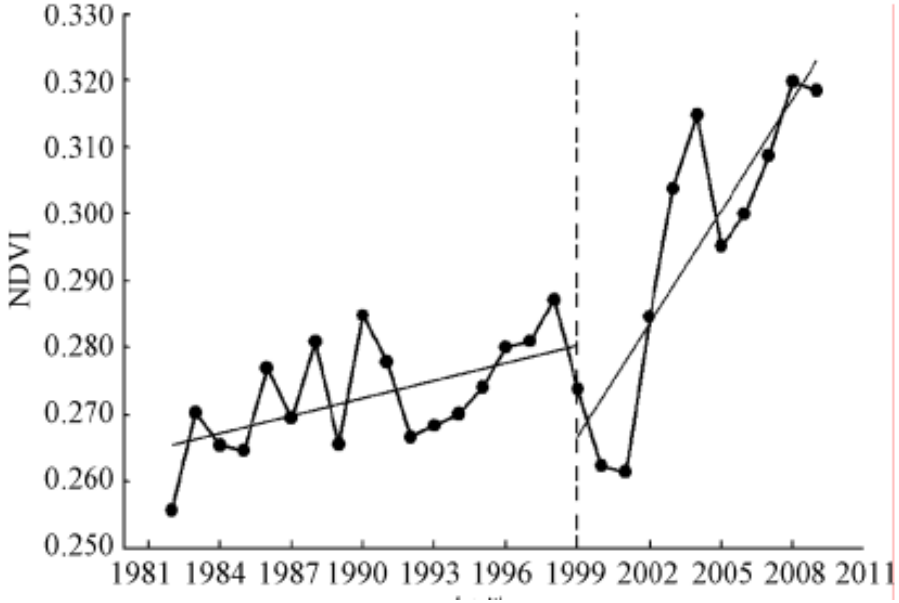
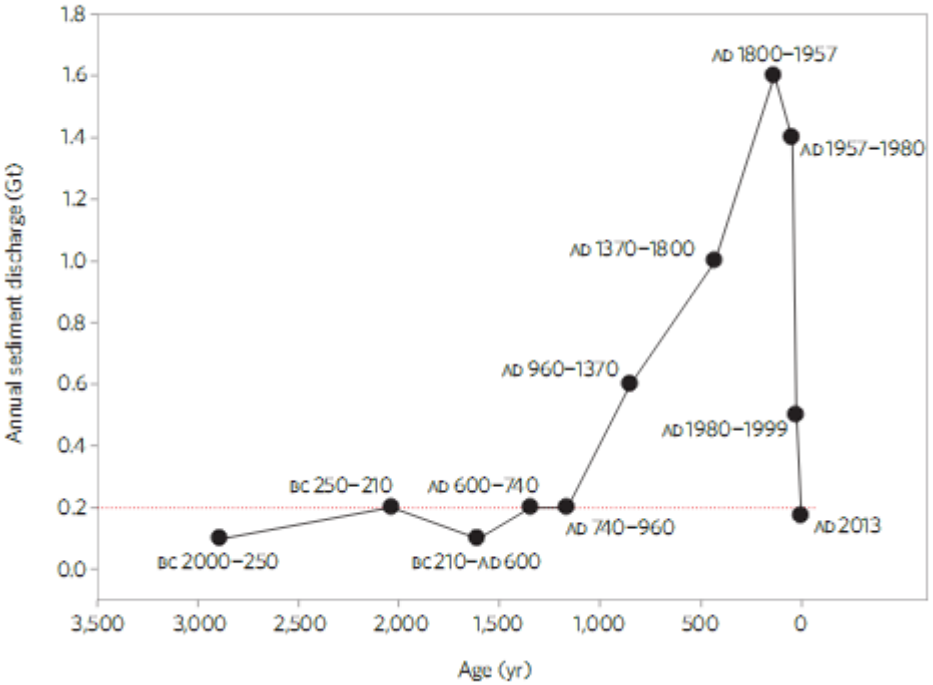
outlines

- Background
- Results
- Conclusion
- Future plans

Location of the Loess Plateau

"Grain to Green" program





China initiated its "Grain for Green" program in 1999 as a large conservation program designed to prevent soil erosion. It is an example of payment for ecosystem services

Does soil erosion reduce by the program? What happened on slope land?

"Grain to Green" program

- Food shortage in some area
- Plant growth limited by soil water content because of high ET of introduced vegetation
- Water resource problem-Yellow River

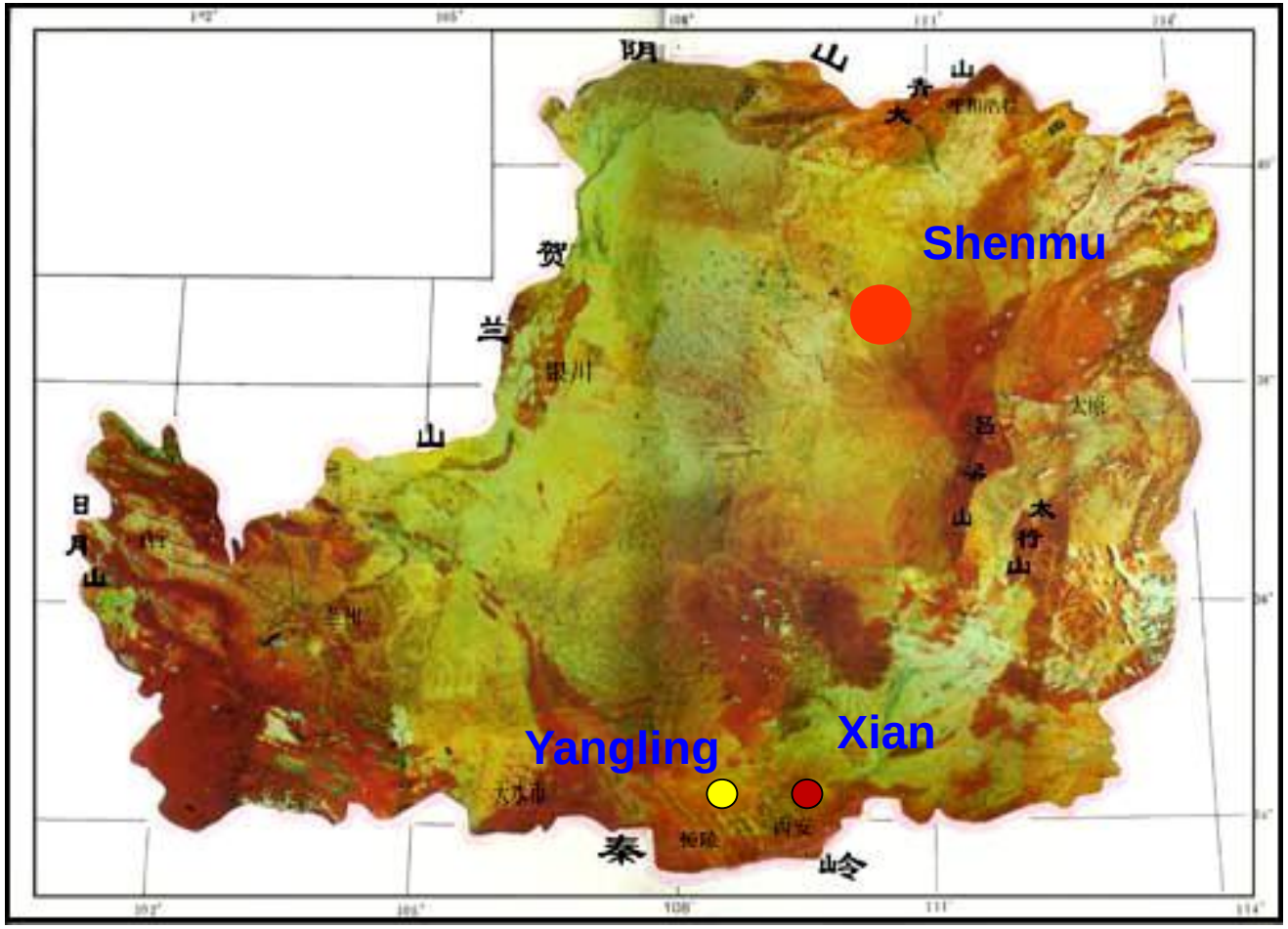
Nature geoscience (2015) doi:10.1038/NGEO2602

$$NPP=383\text{-}528\ g\ C\ m^{-2}\ yr^{-1}$$

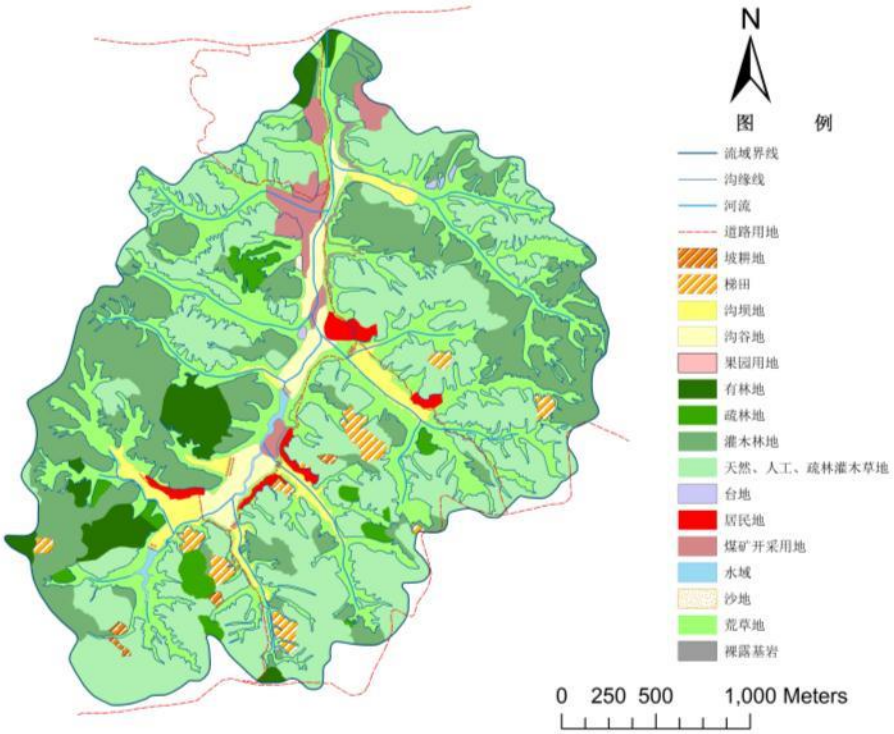
Nature Climate Change (2016) doi:10.1038/nclimate3092

- Grondwater shortage?

Field observation



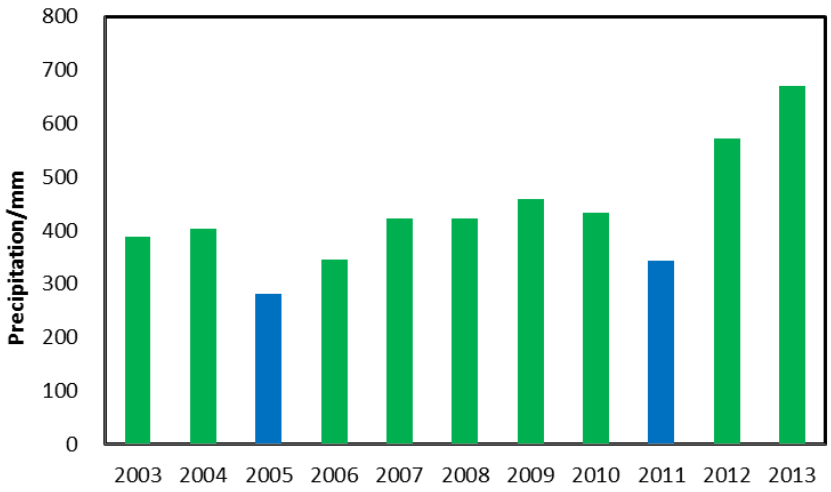
Liudaogou watershed

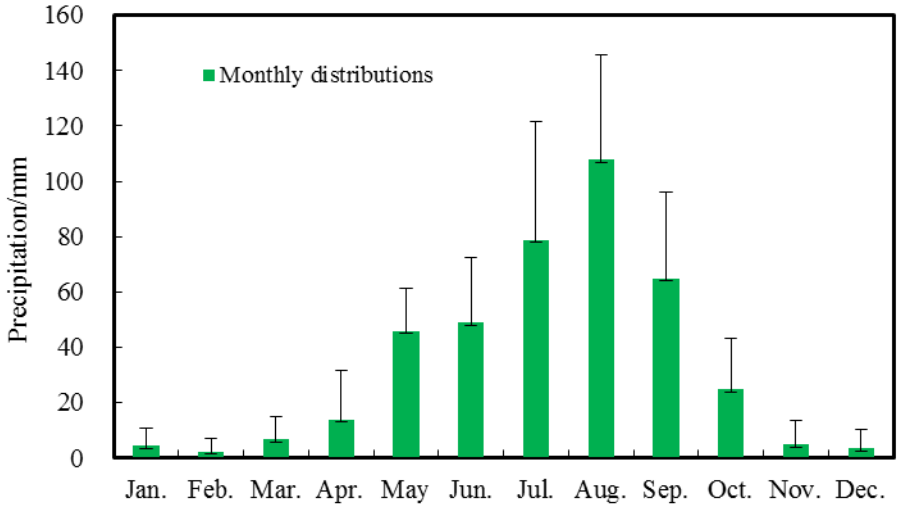


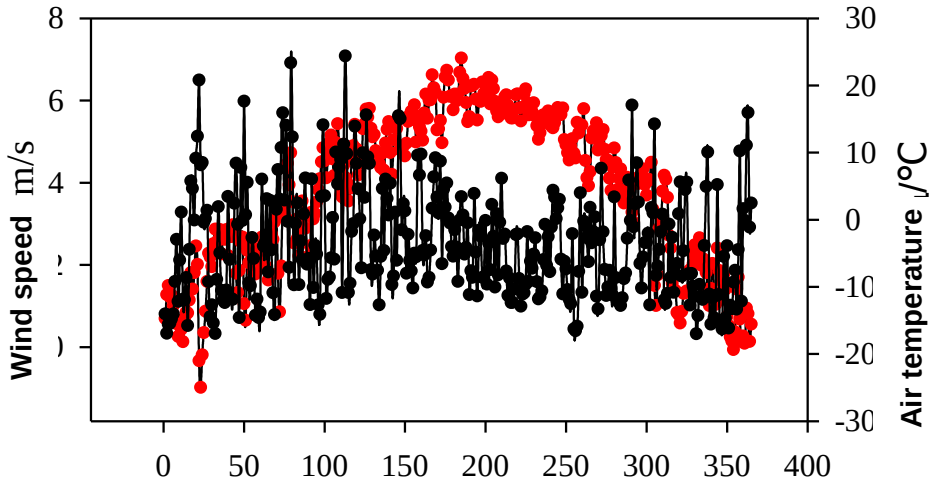
Land use type

Land use type	%
Grass land	56%
Shurbland	22%
forest	5%
farm land	6%
others	11%

Meteorological conditions





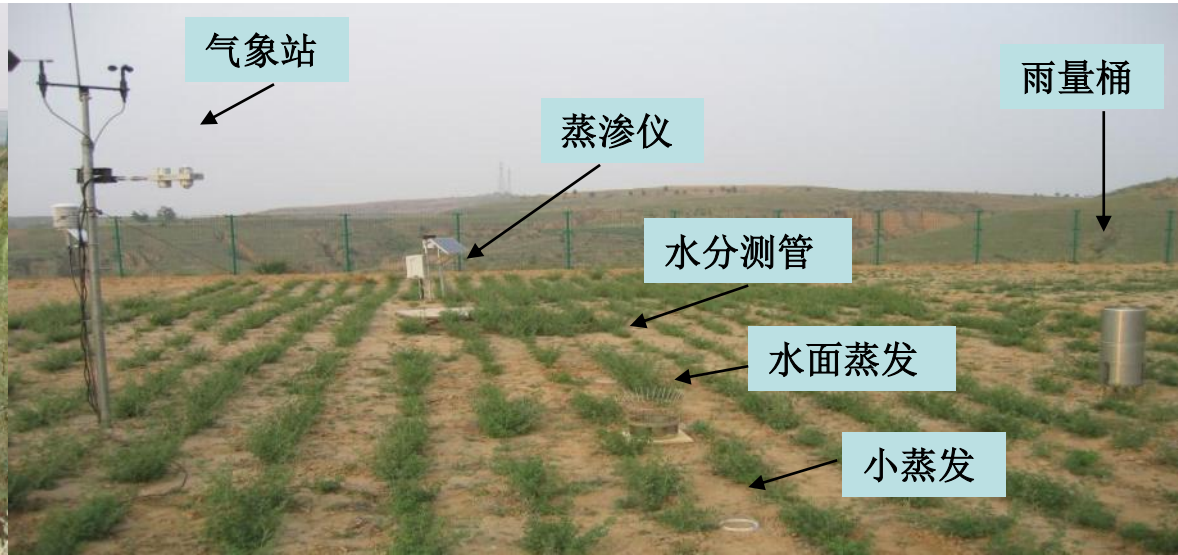


- Mean Precipitation is 400 mm, mainly occurs in Jul, Aug,Sep, lead to water erosion.
- High temperature during rainfall seasons, but wind erosion in winter and spring with heavy wind speed

Field experiments

- Slope runoff plots: 15*4m, 15° three treatments: farmland, alfalfa and abandoned land.

- Terraced plots:20*10m,five plots:bareland, farmland,alfalfa,shrubland (Caragana) and abandoned land.



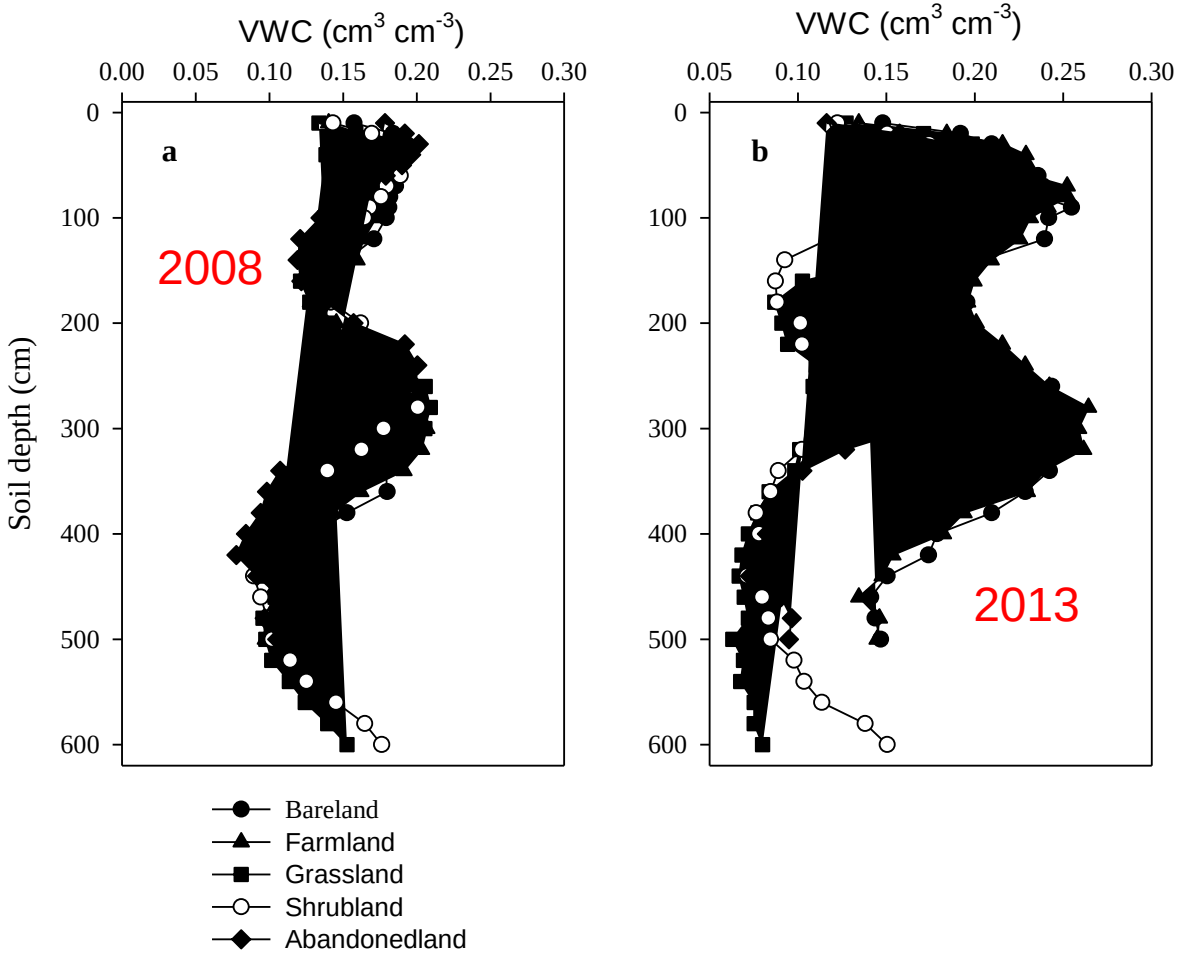
Artificial rainfall test

Rainfall intensity：20mm/h、40mm/h、60mm/h

Rainfall events：1-5 times

Soil water depletion

from terraced fields



Greater differences were observed in October 2013 where it was clear that shrubs and grasses had used more soil water than either the food crops or the weeds in the abandoned land. Furthermore, soil water was significantly recharged in the soil profiles under bare land and farmland

Soil water depletion under land use types

Soil water recharge and root uptake depth from 2008 to 2013 under different land use types at Shenmu, Shaanxi, China.

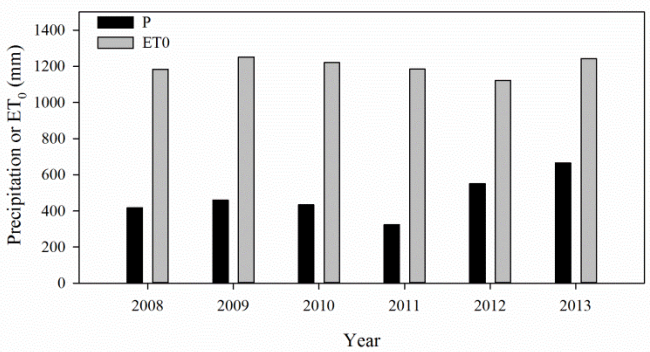
Land use	Maximum Recharge depth (cm)	Maximum water uptake depth (cm)
Bare land	below 500	100
Farmland	below 500	160
Forage land	120	below 600
Shrubland	120	below 600
Abandoned land	260	300

Soil water recharge depths extended deeper than 5 m under bare land and farmland, but introduced forage (alfalfa) and shrub (caragana) species depleted the soil water stores in the 0-6 m layers within a few years, prevented deep soil water recharge

Soil water balance

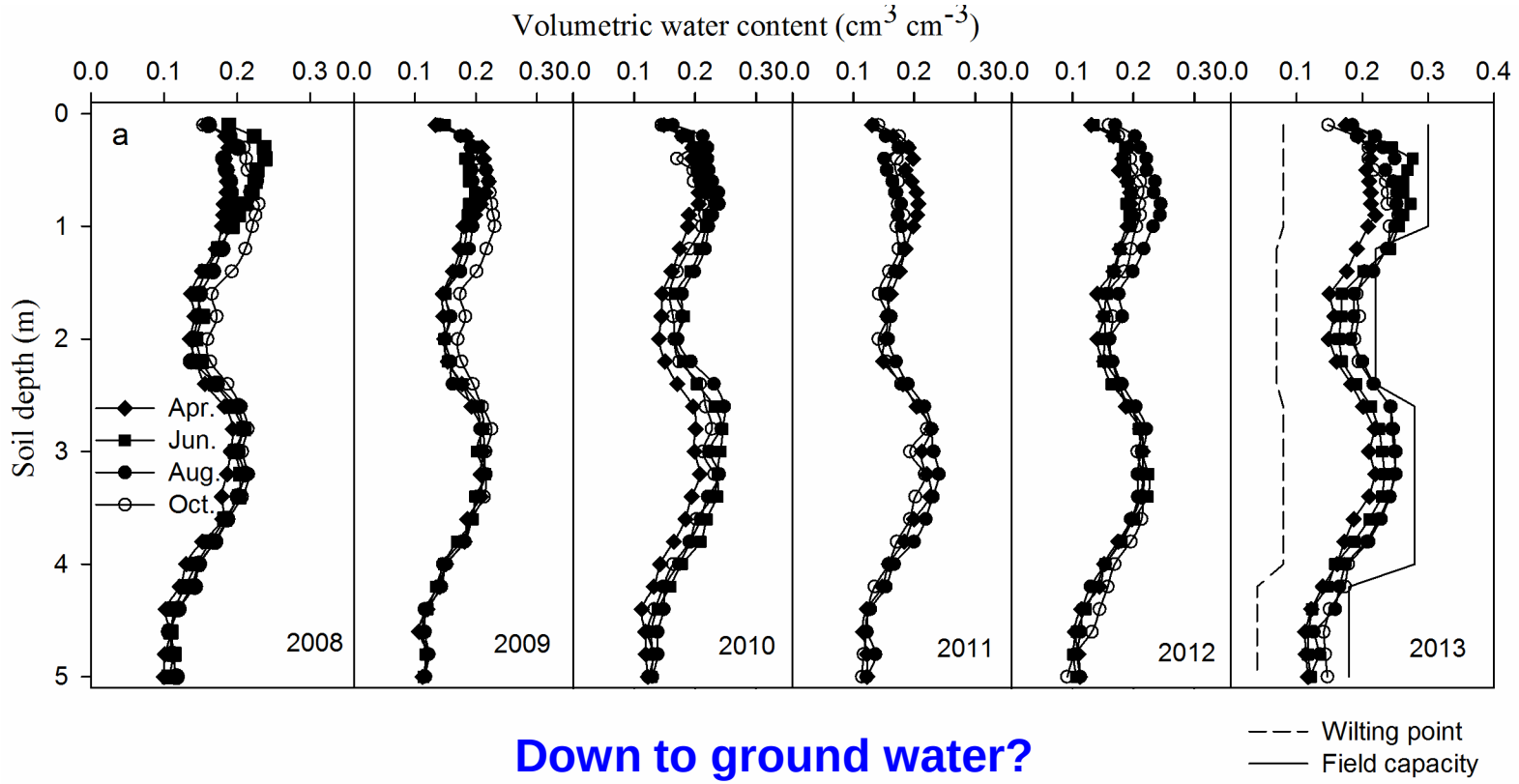
The soil water balances were notably different among the land use types, and the introduced forage land and shrubland exhibited higher water consumption than either the local crops or the native plants growing on the abandoned land

	Precipitation	Bare land	Farmland	Forage land	Shrubland	Abandoned land
W_i[a] 2008	400	785±19[c]A[d]	787±37A	730±52A	739±34A	701±86A
W_f[b]2008		902±10A	916±35A	615±14B	717±26C	697±8C
ΔW[e]		117	130	-115	-22	-4
ET[f]		283	270	515	422	404
W_i 2009	427	862±16A	877±31A	611±15B	708±21C	691±8C
W_f 2009		929±7A	897±42A	541±11B	698±26C	721±20C
ΔW		68	20	-70	-10	30
ET		359	407	497	437	397
W_i 2010	403	842±45A	844±18A	558±17B	697±22C	712±5C
W_f 2010		919±20A	902±24A	497±15B	606±20C	701±21D
ΔW		77	58	-62	-91	-10
ET		326	345	465	494	413
W_i 2011	344	886±21A	882±37A	513±4B	650±5C	725±8D
W_f 2011		840±9A	818±18A	459±1B	521±19C	642±19D
ΔW		-46	-64	-54	-129	-83
ET		390	408	398	473	427
W_i 2012	533	846±44A	768±30B	436±6C	493±8C	631±13D
W_f 2012		903±22A	895±45A	486±6B	491±8B	651±27C
ΔW		57	127	50	-2	20
ET		476	406	483	535	513
W_i 2013	667	891±23A	860±38A	471±5B	503±11B	635±25C
W_f 2013		1040±14A	1050±32A	579±10B	537±8B	738±48C
ΔW		150	190	108	34	103
ET		517	477	559	633	564
Average Precipitation	462					
Average ΔW		70	77	-24	-37	9
Average ET		392	385	486	499	453



Soil water in bare land

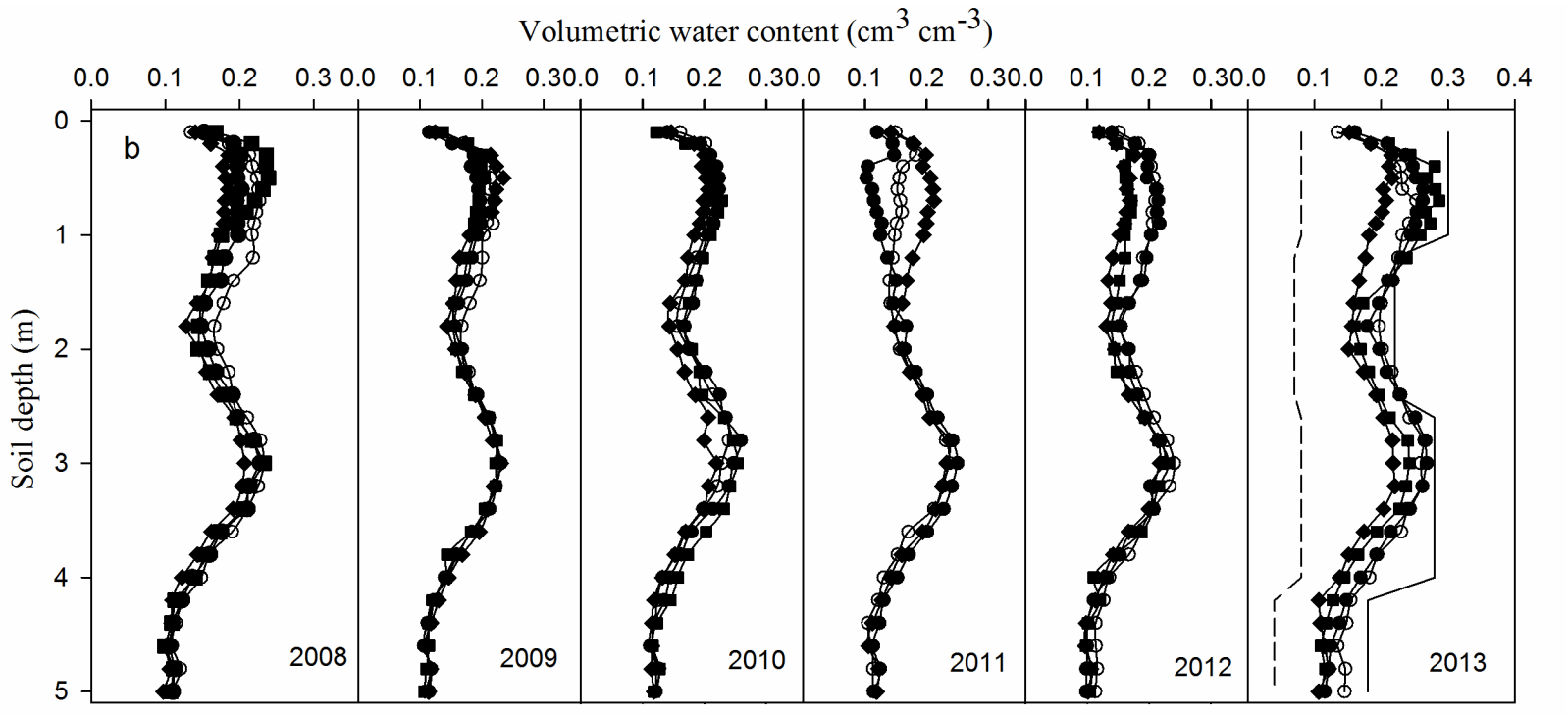
Soil water was recharged to about 5 m on average since the recharge depth was deeper than 5 m in 2010 and 2013 but was less than 3 m in the other study years. The greater recharge depth occurred in 2010 and 2013 due to the higher antecedent water contents and wet years.



Down to ground water?

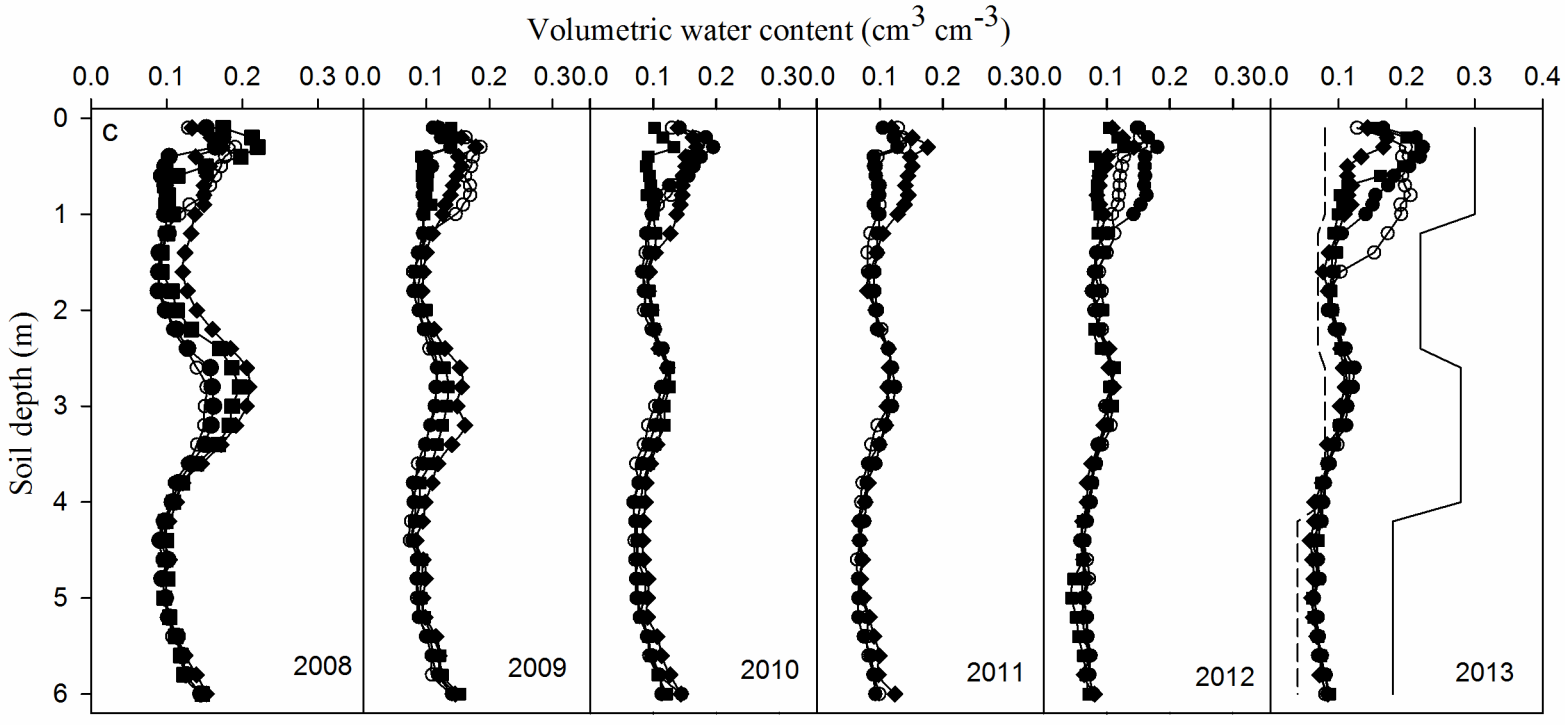
Soil water in crop land

Soil water under farmland had very similar distributions in the soil profile to those in the soils under bare land, which indicated that seasonal rainfall could meet the local food crop water demands.



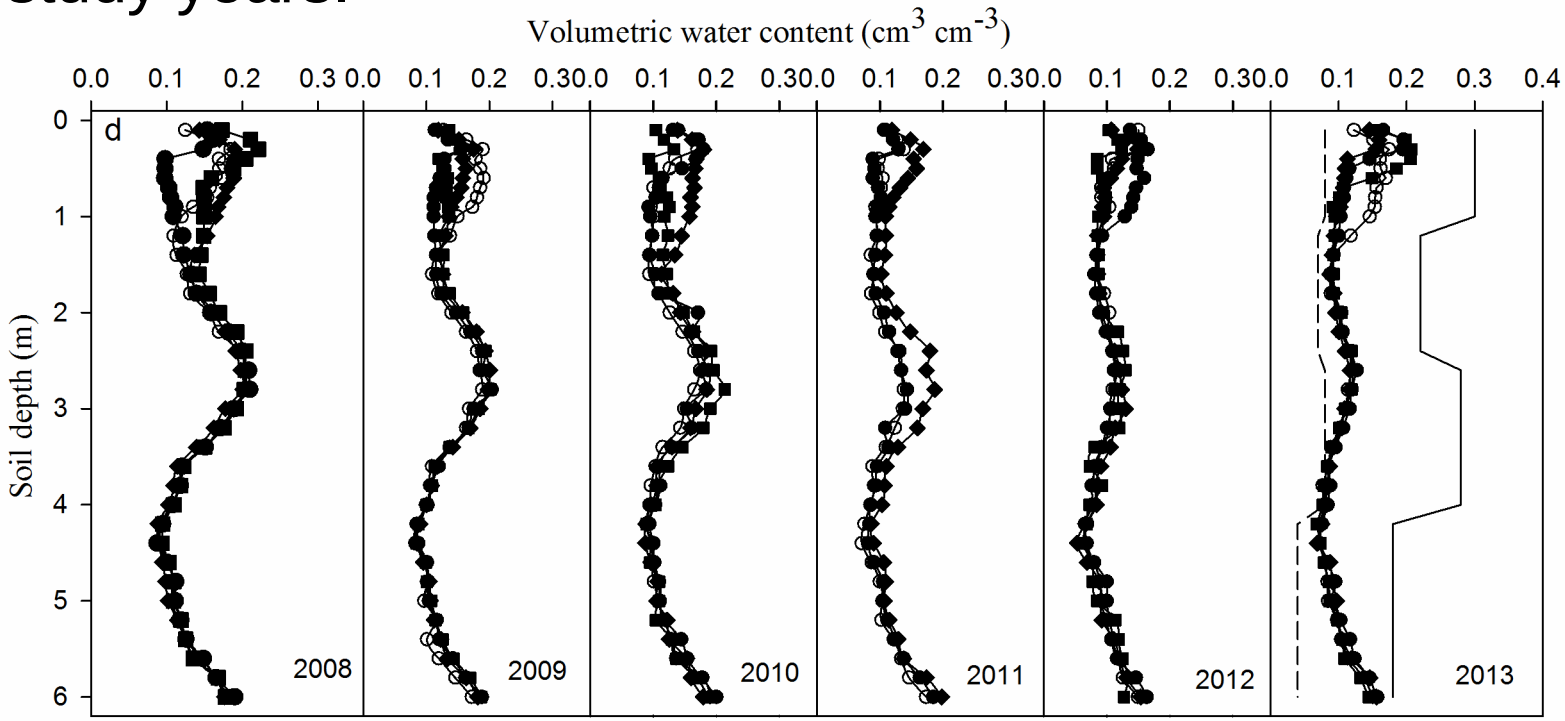
Soil water in alfalfa land

Distinct decreases in the soil water contents in the 1-3.5 m layer of the soil profile were evident in the second year after alfalfa was planted and the affected layer increased to a depth of 4.5 m in the third year. It is possible that root uptake of water may also have occurred from layers deeper than 6 m, which exceeded our measuring depths. The water recharging depth was generally less than 1 m, and only exceeded this depth in 2013 due to the higher rainfall (665 mm).



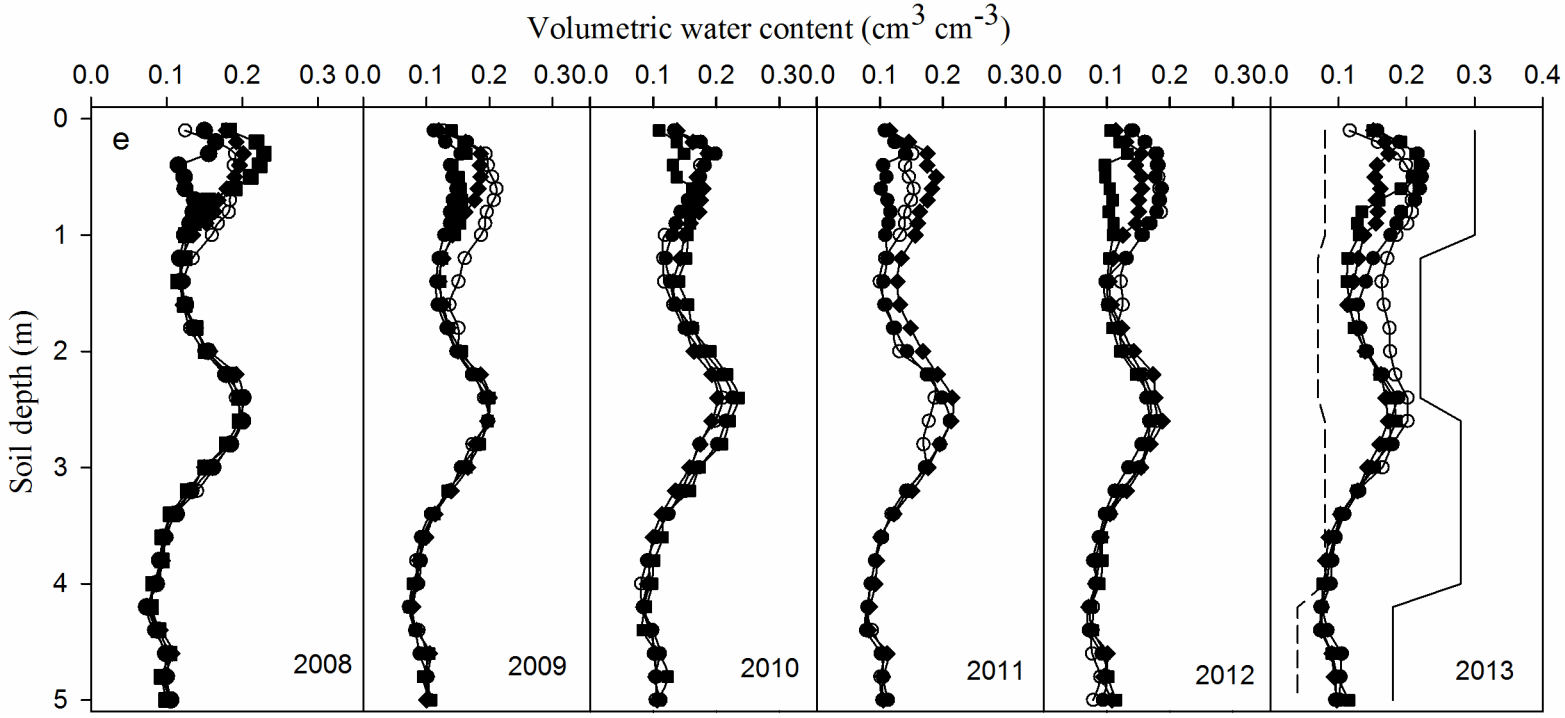
Soil water in shrubland

Caragana consumed deep soil water in 2010 and 2011, and the maximum uptake depth tended to increase from 2009 to 2012, exceeding 6 m. However, rainwater infiltrated to a depth of about 1.2 m during each of the 6 study years.

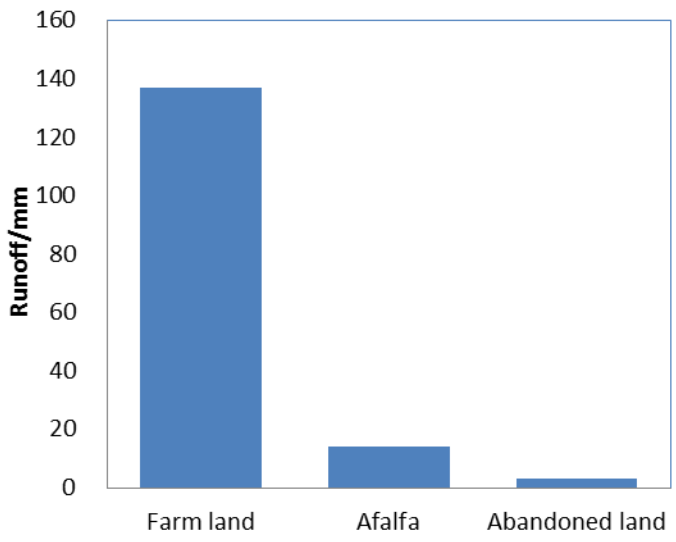


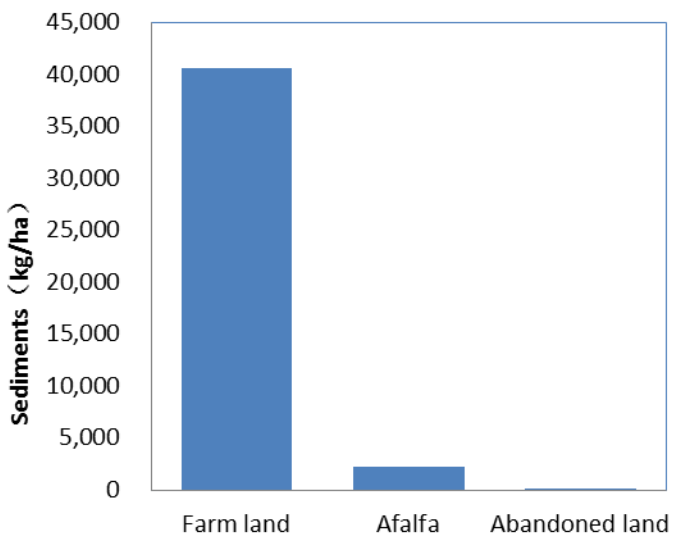
Soil water in abandoned land

Under the abandoned land, the water uptake and recharge depths were observed between those found under farmland and the two restored vegetation .The maximum infiltration depth was 1.6, 3.0 and 2.6 m in 2009, 2010 and 2013 respectively, but the water uptake depth was 0-1 m for five of the study years, but extended down to 3.4 m in 2011.



Soil erosion under different land use





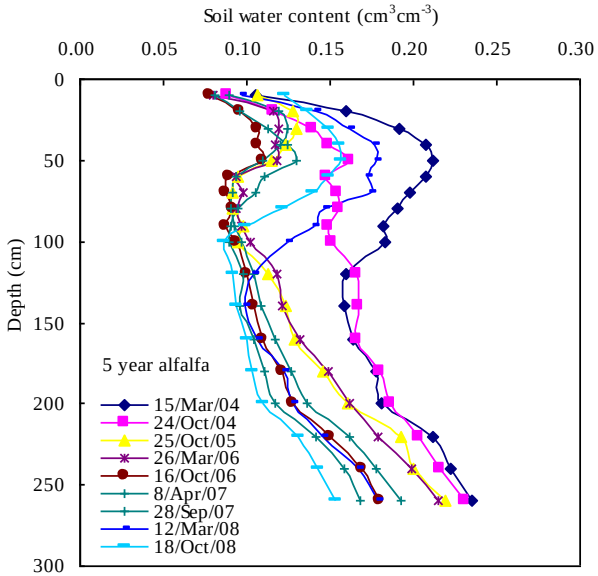
Runoff and sediments were significantly reduced by "Grain to Green"（2007-2012 years）

Yearly runoff from farm land was 23 mm but alfalfa land only 2.3mm,sediment was 5%.

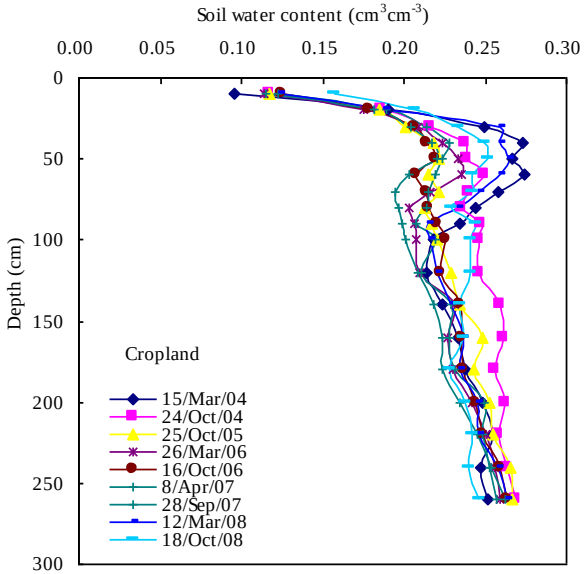
Soil water depletion

from slope field plots

Although non-native vegetation (Alfalfa) can reduce soil erosion, these can also lead to deep soil desiccation



Under water stress, alfalfa can extract water from deep soil layers. The top figure shows alfalfa extracting soil water down to 260 cm. But crop land has more water in soil profile, which may recharge groundwater



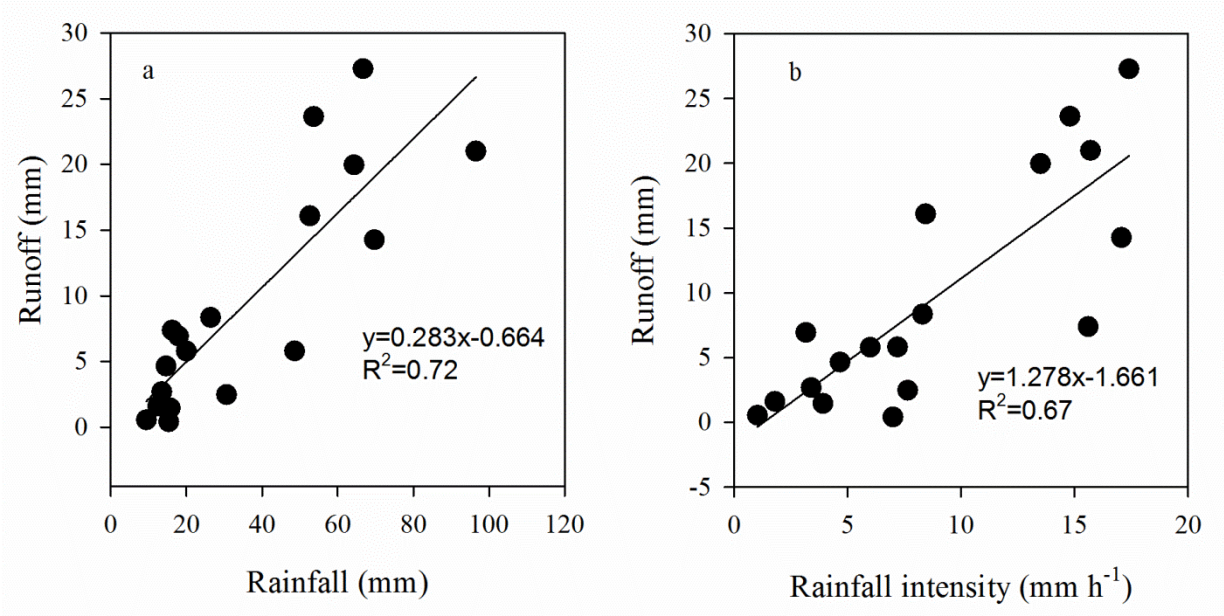
Tips

- ✓ Vegetation restoration significantly reduced the runoff and sediments on slope scales.

- ✓ Soil water can be recharged deeper than 5 m under bare land and farmland, but introduced grass (alfalfa) and shrub (Caragana), species can deplete soil water within a few years (<6 years) and stop deep soil water recharge as exhibited by the negative water balances.

Runoff controlling factors

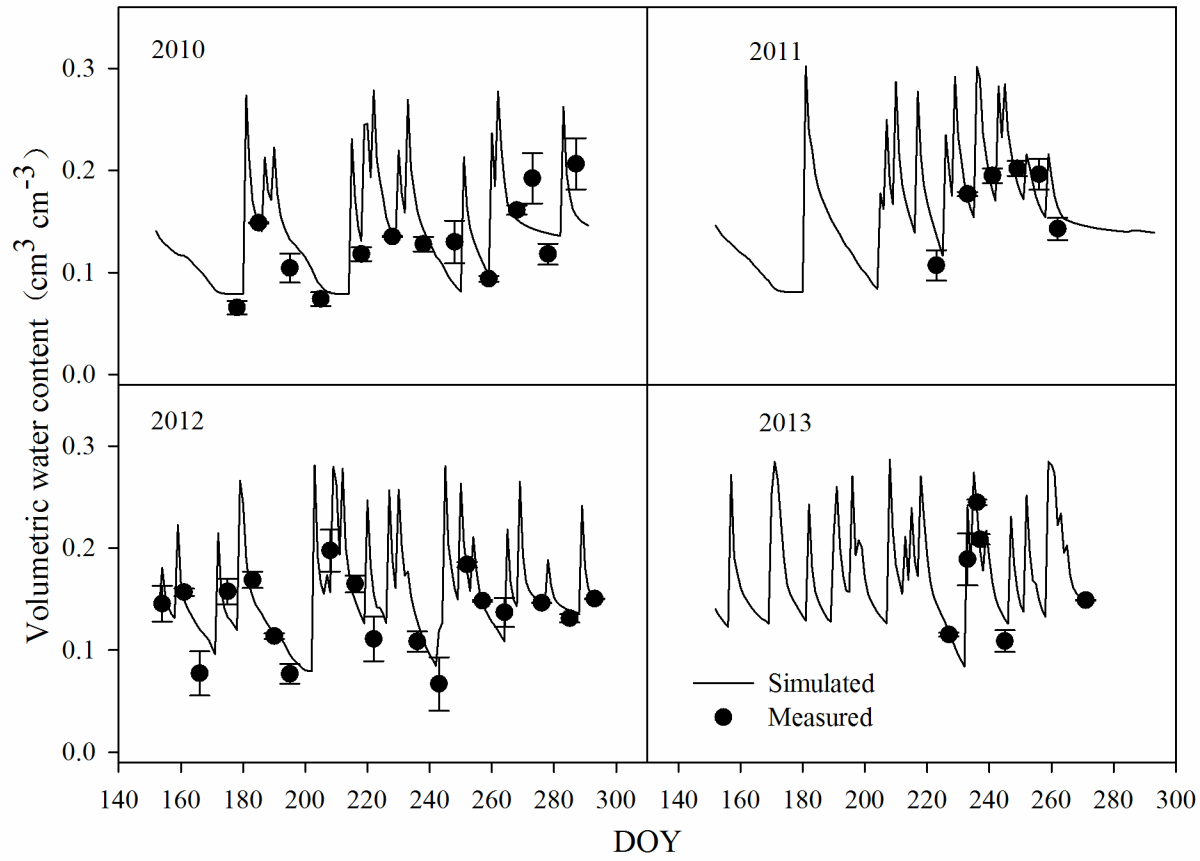
Natural rainfall results



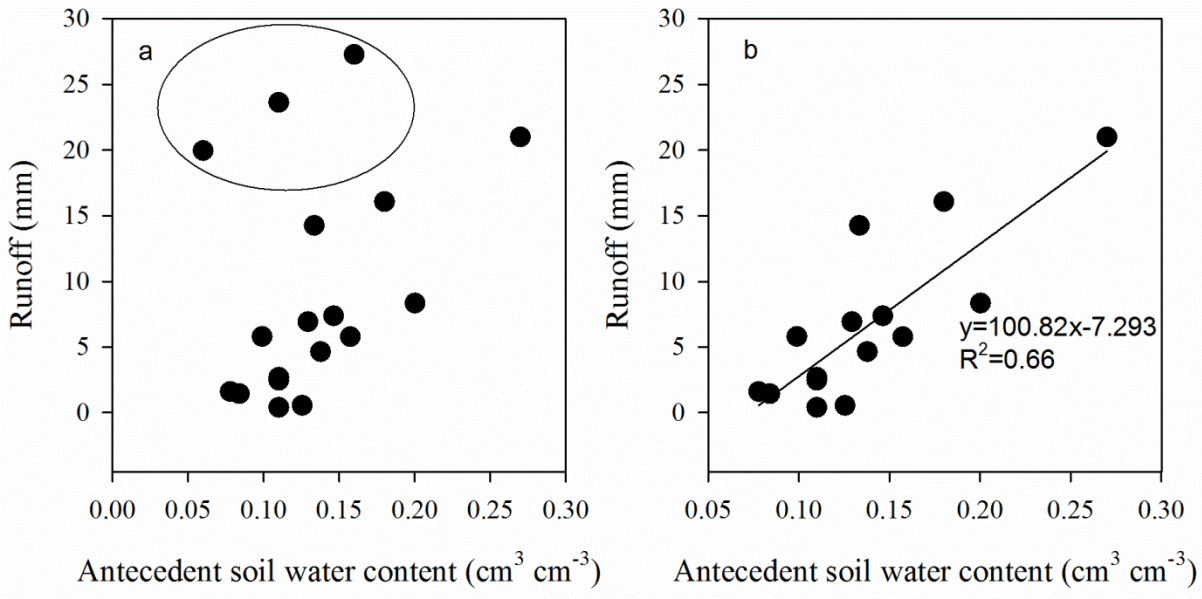
Runoff in farmland plots

Runoff was directly affected by the rainfall amount and intensity

How about the relationship between Antecedent soil water content (ASWC) and runoff?



Daily VWC of the soil shallow layer was simulated by HYDRUS-1D

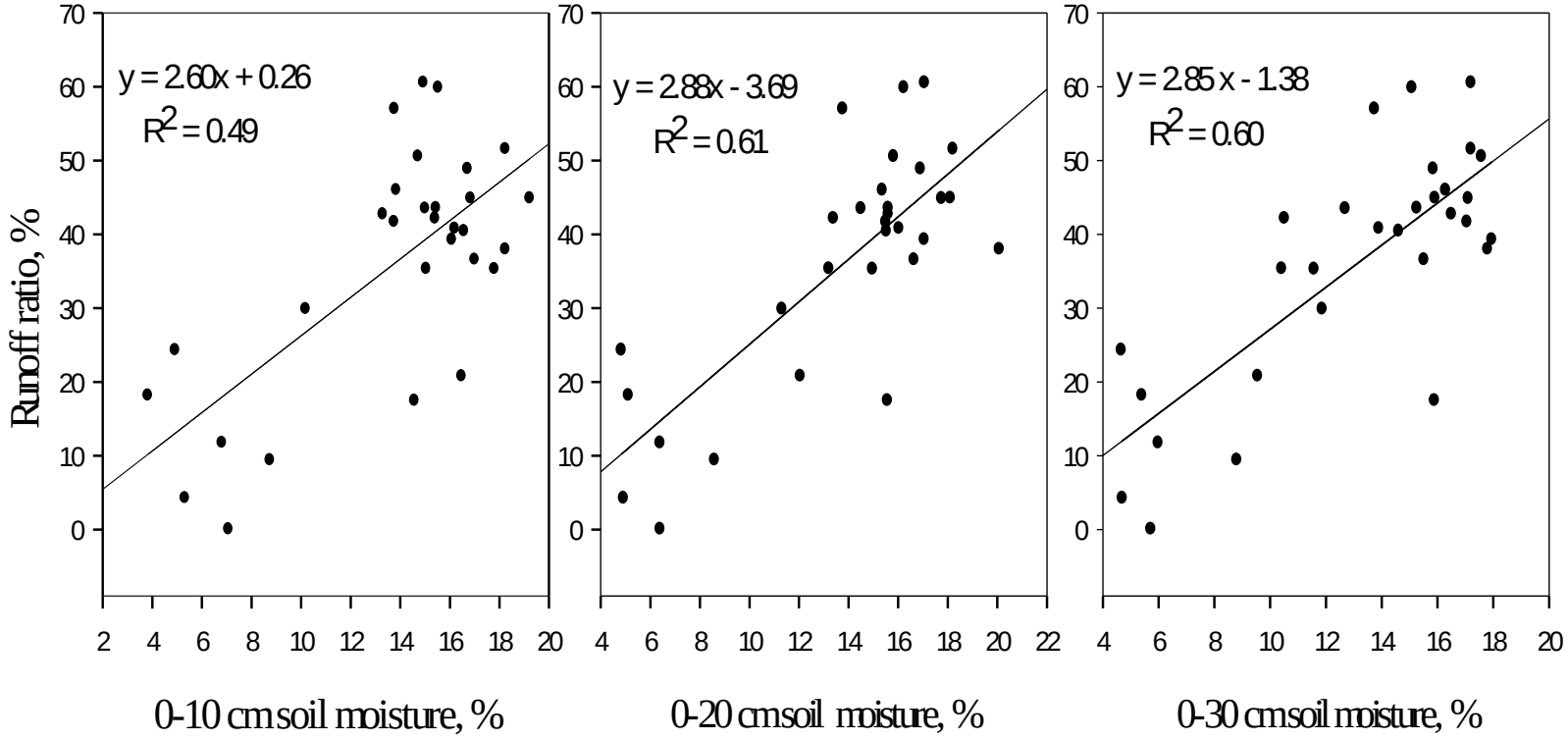


there were three rainfall events that generated very high runoff when the ASWCs were relatively low. The measured meteorological data showed that the rainfall intensities of these three events were greater than 24 mm h-1 and the amounts of rainfall were greater than 54 mm.

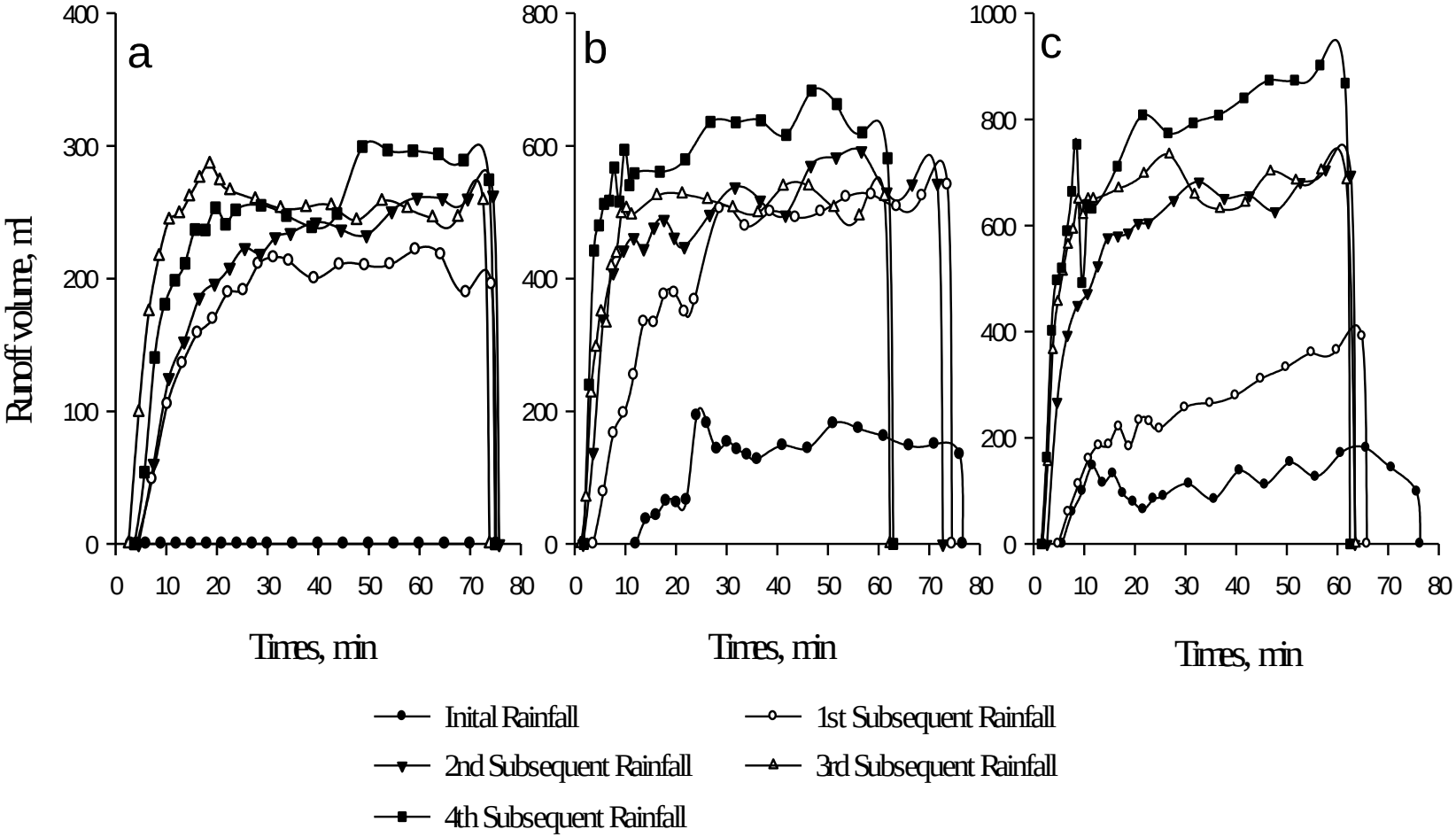
Runoff was typically increased with increases in ASWC

Runoff controlling factors

Artificial rainfall results



Runoff was affected significantly by the ASWC of shallow soils in the artificial field rainfall tests



The subsequent rainfall events could also have significant effects on hydrographic characteristics including time to runoff, runoff volume, soil loss, sediment concentration.

Summary

- ✓ Vegetation restoration significantly reduced the runoff and sediments. Because the coarse soil has high initial infiltration and Ks, soil become drier and initial infiltration get higher. ASWC is very important factor to affect runoff.

- ✓ If shallow ground water could only be supplied by soil water percolation, plants with high biomass (such as alfalfa and caragana) would cut this supply path by completely stopping deep soil recharge.

Future work

- Pasture

  short roots, low ET, runoff but low sediment

  Animal (goat, cattle)---high quality meat

Thanks!!