Ecological Benefit Analysis of Restoration of Degraded Environment by Artificial Tamarix-Cistanche

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Abstract

The Hotan Region in xinjiang, China is a typical arid area. Natural factors determine that the ecological stability of the area is poor, easy to be damaged and difficult to recover. In order to improve the local ecological environment, this study explored an ecology restoration model with the artificial Tamarix-Cistanche. After the long-term monitoring and comparison at four test sites, it was found that this model also increased the per capita income, reduced the poverty in local farmers, and solved the problem of no direct economic benefit from foresting, as well as the following ecological benefits (1) improving the soil properties, and increasing its powder content and fertility, (2) improving the regional microclimate, reducing the daily temperature and relative humidity ranges, and reducing the regional wind speed, (3) restoring the biodiversity, increasing the vegetation coverage and the amount of animals and plants, and enhancing the water and fertility retention of the soil.

Introduction

The Hotan Region in xinjiang, China is a typical arid area. It is the natural factors that result in its reduced amount of living beings, simple ecological structure, poor stability, vulnerability, difficulty in restoration and other fragile characteristics (Fang et al. 2001; Zhang et al. 2011). Growing along the edge of the desert, Tamarix Chinensis is able to resist the desert invasion (Li et al. 2010; Liu et al. 2008). Cistanche is also a valuable herb in traditional Chinese medicine. It is widely used in Chinese medicine and health care non-prescriptively due to is benefits of enhancing the immunity and promoting metabolism. It is concluded that, as a promising business, the Artificial Tamarix-Cistanche model will both improve the living conditions of local farmers and restore the desert ecological environment. On the basis of fully understanding the importance of ecology restoration, this paper explored the ecology restoration model with the Artificial Tamarix-Cistanche, scientifically analyzed and assessed the ecological benefits for Hotan after its implementation, provided important theoretical basis for the promotion and application of ecology restoration project, and played a practical role in promoting the sustainable development of the local agriculture and forestry.

Materials And Methods

Four representative and monitorable objects (Moyu County, Yutian County, Cele County, and Pishan County) in Hotan were selected for the Restoration Project with the Artificial Tamarix-Cistanche,. The ecological benefits (including the local soil improvement, regional microclimate conditioning, and biodiversity restoration) after the implementation of the ecology restoration project with the Artificial Tamarix-Cistanche, were analyzed by way of comparing the long-term monitoring results and data at the test sites. Wherein, the monitored sites were 4-year-old Artificial Tamarix Chinensis forests, and the control sites were bare desert nearby.

Table 1
The proportion of soil particle size distribution in different experimental areas(%)

Areas	Sample	Depth	Clay	Average value	Silt	Average value	Sand	Average value
MoYu county	Monitoring sample	0-20cm	0	0	1.93	7.34	98.07	92.66
		20-40cm	0		7.98		92.02	
		40-60cm	0		12.12		87.88	
	Control sample	0-20cm	0	0	5.81	5.71	94.19	94.29
		20-40cm	0		4.88		95.12	
		40-60cm	0		6.43		93.57	
YuTian county	Monitoring sample	0-20cm	0	0	2.35	6.32	97.65	93.68
		20-40cm	0		6.18		93.82	
		40-60cm	0		10.42		89.58	
	Control sample	0-20cm	0	0	0.64	1.40	99.36	98.60
		20-40cm	0		1.59		98.41	
		40-60cm	0		1.96		98.04	
CeLe county	Monitoring sample	0-20cm	1.00	1.62	3.25	7.57	95.75	90.81
		20-40cm	1.56		8.19		90.25	
		40-60cm	2.31		11.27		86.42	
	Control sample	0-20cm	0	0.16	5.93	5.9	94.07	93.95
		20-40cm	0.17		5.61		94.22	
		40-60cm	0.31		6.16		93.53	
PiShan county	Monitoring sample	0-20cm	0	0	2.34	6.88	97.66	93.12
		20-40cm	0		7.97		92.03	
		40-60cm	0		10.32		89.68	
	Control sample	0-20cm	0	0	3.21	3.81	96.79	96.19
		20-40cm	0		3.76		96.24	
		40-60cm	0		4.45		95.55	

Results

Soil improvement

Changes in soil properties

The mechanical composition of all soil samples was determined. It can be found from the results (Table 1) that the powder contents at different depths of the topsoil taken from the four test sites were significantly higher than those from the control sites. The average values of these contents are as follows: Moyu 7.34%, Yutian 6.32%, Cele 7.57% and Pishan 6.88%, about 22.21%, 77.85%, 21.27% and 44.62% higher than the control sites respectively. The overall performance of the restoration are as follows: Yutian > Pishan > Moyu > Cele.

Table 2
Analysis results of soil chemical properties in different experimental areas(g/Kg)

Areas	Sample	Depth	Organic matter	Average value	Organic carbon	Average value	Total N	Average value	Total P	Average value	Total K	Average value
MoYu county	Monitoring sample	0-20cm	49.01	45.10	0.60	0.56	0.08	0.08	0.59	0.57	17.01	16.83
		20-40cm	45.37		0.59		0.08		0.56		16.92	
		40-60cm	40.91		0.48		0.08		0.55		16.56	
	Control sample	0-20cm	41.15	39.44	0.67	0.53	0.08	0.06	0.54	0.52	16.83	16.66
		20-40cm	40.24		0.49		0.07		0.52		16.79	
		40-60cm	36.92		0.42		0.05		0.51		16.35	
YuTian county	Monitoring sample	0-20cm	50.19	40.79	0.74	0.54	0.10	0.07	0.54	0.51	19.55	19.31
		20-40cm	39.21		0.58		0.07		0.50		19.37	
		40-60cm	32.97		0.61		0.05		0.48		19.02	
	Control sample	0-20cm	44.70	36.68	0.66	0.78	0.08	0.05	0.45	0.38	17.70	17.33
		20-40cm	35.42		0.50		0.05		0.39		17.57	
		40-60cm	29.93		0.45		0.04		0.30		16.73	
CeLe county	Monitoring sample	0-20cm	60.46	54.43	0.89	0.68	0.11	0.08	0.57	0.57	19.05	19
		20-40cm	51.61		0.76		0.08		0.58		19.07	
		40-60cm	51.22		0.69		0.07		0.55		18.88	
	Control sample	0-20cm	48.89	46.53	0.72	0.77	0.09	0.07	0.56	0.5	17.88	17.36
		20-40cm	49.72		0.70		0.07		0.50		17.65	
		40-60cm	40.99		0.63		0.06		0.44		16.55	
PiShan county	Monitoring sample	0-20cm	65.34	57.21	0.87	0.59	0.11	0.09	0.59	0.55	18.87	18.53
		20-40cm	59.22		0.76		0.09		0.54		18.57	
		40-60cm	47.06		0.68		0.08		0.52		18.14	
	Control sample	0-20cm	51.22	43.91	0.70	0.56	0.09	0.07	0.53	0.48	17.92	17.58
		20-40cm	42.24		0.58		0.07		0.49		17.68	
		40-60cm	38.26		0.50		0.06		0.43		17.13	

Changes in soil chemical properties

The soil organic matter, organic carbon, total N, total P, total K and other chemical components were determined. It can be found from the results (Table 2) that these parameters of the soil layers of the four test sites were higher than those of the control sites. The average soil organic matter content in the order from large to small is as follows: Pishan 57.21 g/kg, Cele 54.43 g/kg, Moyu 45.10 g/kg and Yutian 40.79 g/kg, about 30.29%, 16.97%, 14.35% and 11.19% higher than the control sites respectively, of which the 0–20 cm layer taken from Pishan County showed a highest value of 65.34 g/kg, about 1.28 times of the same layer taken from the corresponding control site. The average soil organic carbon in the order from large to small is as follows: Cele 0.78 g/kg, Pishan 0.77 g/kg, Yutian 0.64 g/kg, Moyu 0.56 g/kg, about 14.15%, 29.78%, 19.88% and 5.69% higher than the control sites respectively, of which the 0–20 cm layer taken from Pishan County showed a highest value of 0.89 g/kg, about 1.24 times of the same layer taken from the corresponding control site. For the total N, total P and total K, the average total N in the soil layers taken from Pishan County was highest of 0.093 g/kg, the average total P in the soil layers taken from Moyu County and Cele County was highest of 0.57 g/kg, and the average total K in the soil layers taken from Yutian County was highest of 19.31 g/kg.

Regional microclimate improvement

Temperature changes

In this study, the temperature was observed in each artificial Tamarix Chinensis forest at each test site during the daytime, and their daily average temperature ranges were calculated and compared with the respective control sites. It can be seen from Table 3 that significant reduction of the day-time daily temperature ranges in April (0.5–1.5 °C) and August (4.4–4.9 °C) in the artificial Tamarix Chinensis forests at the four test sites were observed.

Table 3
Daily temperature range in different experimental areas(°C)

Time	MoYu county		YuTian county		CeLe county		PiShan county	
	Monitoring sample	Control sample	Monitoring sample	Control sample	Monitoring sample	Control sample	Monitoring sample	Control sample
Apr.	9.6	10.8	9.8	10.3	8.9	10.1	9.2	10.7
Aug.	8.5	13.4	9.3	13.7	8.3	12.9	8.5	13.3

Humidity changes

Also in this study, the humidity was observed in each artificial Tamarix Chinensis forest at each test site during the daytime, and their daily average humidity ranges were calculated and compared with the respective control sites. It can be seen from Table 4 that significant reduction of the day-time daily humidity ranges in April (1.4–2.2 °C) and August (5.9–8.9 °C) in the artificial Tamarix Chinensis forests at the four test sites were observed.

Table 4
Diurnal range of relative humidity in different experimental areas(°C)

Time	MoYu county		YuTian county		CeLe county		PiShan county	
	Monitoring sample	Control sample	Monitoring sample	Control sample	Monitoring sample	Control sample	Monitoring sample	Control sample
Apr.	22.8	24.2	19.0	21.0	22.0	23.8	21.6	23.8
Aug.	29.8	35.7	30	37.6	29.7	38.6	29.6	36.2

Table 5
The variation of wind speed in different experimental areas and position on April

Areas	MoYu county		YuTian county		CeLe county		PiShan county		Average value
Item	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)
Control sample	6.17	100	5.84	100	5.21	100	5.32	100	5.64
Upwind	5.89	95.46	5.18	88.7	4.77	91.55	4.69	88.16	5.13
In the forest	5.23	84.76	4.51	77.23	4.34	83.3	4.11	77.26	4.55
Leeside	4.64	75.2	4.17	71.4	4.07	78.12	3.93	73.87	4.20

Table 6
The variation of wind speed in different experimental areas and position on August

Areas	MoYu county		YuTian county		CeLe county		PiShan county		Average value
Item	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)	Relative wind speed(%)	Wind speed(m/s)
Upwind	2.71	100	3.21	100	2.84	100	2.53	100	2.82
In the forest	2.55	94.1	2.91	90.65	2.6	91.55	2.33	92.09	2.59
Leeside	1.36	50.18	1.24	38.63	1.15	40.49	1.01	39.92	1.19
Upwind	0.75	27.68	0.98	30.53	0.87	30.63	0.69	27.27	0.82

Wind speed changes

The wind speed was measured in the artificial Tamarix Chinensis forests at each test site. It can be seen from Tables 5 and 6 that the Artificial Tamarix Chinensis forests at the four test sites could effectively attenuate the wind speed. In April, the measured average wind speed at each test sites was 5.13 m/s on the windward side, about 90.97% of that at the control sites. The significant relative wind speed reduction was observed in the forest belt, about 80.64% of that at the control sites. The best relative wind speed reduction was observed on the leeward side, about 74.65% of that at the control sites. In August, the average wind speed on the windward side for all test sites was of 2.59 m/s, equal to 92.10% of the average for all control sites. The relative wind speed in the forest belt was significantly decreased from the speed on the windward side, equal to 42.31% of the average for all control sites. The largest wind speed decrease was observed on the leeward side, equal to 29.08% of the average for all control sites.

Biodiversity Restoration

The plant samples taken from the Artificial Tamarix Chinensis forests at the test sites were surveyed. It can be seen from Table 7 that the Artificial Tamarix Chinensis forests at the four test sites significantly improved the vegetation coverage. In the Tamarix Chinensis forest in Moyu County, the average tree height was of 135.5 cm with high coverage, but low plant diversity. There were only a few herbaceous plants in this Tamarix Chinensis forest, such as salsola collina and agriophyllum squarrosum. In the Tamarix Chinensis forest in Yutian County, the average tree height was of 113 cm, with low coverage. There were many areas covered by the reed. In the Tamarix Chinensis forest in Cele County, the average tree height was of 164 cm, with low coverage and few plant species. There was some salsola collina in addition to reed. In the Tamarix Chinensis forest in Pishan County, the average tree height was of 157 cm with high coverage and increased number of species. There were many herbaceous plants such as reed, apocynum venetum and salsola collina.

Table 7
Investigation and statistics of plant sample in different experimental areas

Areas	MoYu county	YuTian county	CeLe county	PiShan county
The number of plants(100 square meters)	60	41	53	47
Height(cm)	135.5	113	164	157
Coverage(%)	23	10	15	21
Herbage	Salsola collina pall, Agriophyllum squarrosum	Reed	Salsola collina pall	Reed, Apocynum venetum, Salsola collina pall

Discussion

Soil improvement benefit analysis

The soil texture is one of the important physical properties of soil, which is also an important index. The survival and growth of the Artificial Tamarix Chinensis forests greatly depend on the powder content(Deng et al. 2016; Dexter et al. 2004). As seen from the vertical distribution of the soil grain size (Fig. 1), the grain size composition was changed as follows: the mass percentage of sand decreased with the increase of the soil depth, and the mass percentage of powder and clay increased with the increase of the soil depth. The proportion of the powder in the soil texture at each test site was slightly higher than that of each control site. It indicates that the growth of the Artificial Tamarix Chinensis forests could improve the soil texture and contribute, to a certain extent, to the growth of the herbaceous plants within the forest, which is further beneficial to improve the soil texture. However, it takes a long time before significant change can be observed other than the short period of this project. The soil fertility generally depends on the soil organic matter as a key material basis.

Figure 1 Vertical distribution of soil particle size in different experimental areas

The soil organic matter content is an important indicator of soil fertility(Six et al. 2000; Yin et al. 2010). In this project, the content of the organic matter in each soil layer at each test site was higher than that at each control site respectively (Fig. 2). For the distribution in soil, the organic matter in the layer between 0–20 cm was of highest and gradually decreased in layers from 20 to 60 cm, but not significant. It is speculated that Tamaxix Chinensis was inoculated with the Cistanche and greatly affected by human activities, such as annual ploughing, inoculation and Cistanche harvesting, causing a large amount of organic matter buried in the lower layers. Therefore, little difference in organic matter content was observed among different soil layers.

Figure 2 Vertical distribution of soil organic matter in different experimental areas

The soil organic carbon is a key component of the arable soil, and plays a very important role in soil fertility, environmental protection and sustainable development of farmlands(Sartori et al. 2007; Su et al. 2018; Wang et al. 2010; Zhang et al. 2018). In this project, higher content of organic carbon in each layer at each test site (except Moyu County) was observed than that at the corresponding control site (Fig. 3). Since the organic carbon comes from the soil organic matter, the same trend can be observed in terms of organic carbon and organic matter, i.e. decreasing from top to bottom.

Figure 3 Vertical distribution of soil organic carbon in different experimental areas

Same as the organic matter, the three necessary nutrients for plant growth, N, P, and K, are mainly derived from the accumulation of biological organisms (Zuo et al. 2010). In this project, the distribution of soil total N, total P and total K at each test site were basically the same as that of the organic matter, and their contents were higher than those at the control sites (Fig. 4). Therefore, it can be seen that the growth of the Artificial Tamarix Chinensis forests could enhance the supply of soil N, P and K. And the individual difference may depend on the different soil parent material and soil organic matter. In addition, the annual harvesting of Cistanche could also take away certain amount of N, P and K, an unignorable reason accounting for such difference.

Figure 4 Vertical distribution of soil total N, P and K in different experimental areas

To clarify the correlation among the physical and chemical properties of the soil at the ecology restoration sites, the correlation analysis of the average values for the different indicators of each soil layer was conducted. Let X1: organic matter (g/kg), X2: organic carbon (g/kg), X3: total N (g/kg), X4: total P (g/kg), X5: total K (mg/kg), and X6: grain size < powder (%), and the relevant analysis results are shown in Table 8.

Table 8
Correlation degree of soil physical and chemical properties factors

	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1.00	0.84	0.51	0.55	0.52	0.50
X_2		1.00	0.12	0.13	0.63	-0.46
X_3			1.00	0.25	-0.43	0.34
X_4				1.00	-0.59	0.74
X_5					1.00	0.03
X_6						1.00

It can be seen from the above table that there is close correlation among the soil physical and chemical factors. Significant positive correlation among soil organic matter, organic carbon, total N, total P and total K was observed to be consistent with the theory. Secondly, significant positive correlation was also observed between the soil organic matter content and soil grain size < powder content, indicating that with the increase of the organic matter content in soil, there were more frequent microbial activities, faster decomposition rate of the sand and better optimization and improvement in soil texture.At the same time, there is close correlation between the composition of soil particles and the content of N and P in soil. In general, higher proportion of fine particles generates finer texture, and it is more favorable for the absorption and storage of the nutrients. The increased nutrient contents could be, in turn, conducive to the formation of the soil aggregate structure and to the improvement of the soil stability(Yang et al. 2016; Yi et al. 2007).

Regional microclimate improvement benefit analysis

The regional microclimate refers to that, within the limited range of the Artificial Tamarix Chinensis forests in the ecology restoration area, the local meteorological factors, such as light, temperature and humidity, are significantly different from those outside of the range. Its formation is due to the radiation characteristics of the underlying surface and the different exchange process with the atmosphere(Dale et al. 1999).

In this project, there was consistency in the daily temperature ranges of the artificial Tamarix Chinensis forests at all test sites (Fig. 5). The daily trend was to increase and then gradually decrease, with a parabolic shape. The highest temperature was observed at about 14:00 in local time. In general, the regulation of the air temperature with the windbreak forest in August is more obvious than that in April. This is due to the hot temperature in summer, the lush canopy, the reduced net radiation, the lowered solar radiation and long-wave radiation at the arrival zone, and absorption of much heat by the transpiration of the trees. In general, the regional microclimate improvement of temperature by the Artificial Tamarix Chinensis forest is mainly reflected in the stabilization of the temperature on both low and high ends of the temperature range.

Figure 5 Diurnal temperature variation during April and August in different experimental areas

There was consistency in the daily relative humidity ranges of the artificial Tamarix Chinensis forests at all test sites. The relative humidity at the test sites was higher than that at the control sites both in April and August (Fig. 6). The effectively increased relative humidity within the forests was mainly due to the occlusion of the canopy, reduced wind speed, weakened turbulent exchange, hindered diffusion of water vapor, and prolonged detention of the water vapor from the canopy transpiration and soil evaporation. The daily trend was exactly opposite to the temperature. It was decreased and then increased with an inverted parabolic shape. The lowest relative humidity was observed at about the time of the highest temperature (14:00–16:00) when there were calm wind and fastest transpiration of the leaves and crops. In addition, the regulation of the air relative humidity with the windbreak forest in August is more obvious than that in April. This is due to the lush canopy blocking the exchange between inside and outside of the forest and to the powerful root system absorbing enough soil moisture for the consumption of the transpiration and supplying the moisture in the air(Freedman et al. 2014; Yin et al. 2007).

Figure 6 Diurnal relative humidity variation during April and August in different experimental areas

Reduced wind speed is the most basic benefit of Artificial Tamarix Chinensis forests. In this project, significantly reduced wind speed by the Artificial Tamarix Chinensis forests was observed (Fig. 7). The wind speed reduction in August was significantly better than that in April, due to the lush canopy in summer. The leaves were less in April and the wind blocking was largely achieved by the branches of the trees. The windproof performance was elevated in August due to the growth of branches and leaves, the friction of which, together with the trunks, consumed more kinetic energy of the wind (Liu et al. 1996; Ma et al. 2009; Okin et al. 2006).

Figure 7 Change of relative wind speed during April and August in different experimental areas

Biodiversity Restoration Benefit Analysis

After the implementation of the ecology restoration project with the Artificial Tamarix-Cistanche, the forest vegetation coverage was enlarged to provide habitat for the growth and development of other living creatures, and therefore the biodiversity was improved especially at the test sites with significantly enlarged coverage (Fig. 8). The increased plant roots in the soil due to the increased plant mass played a great role in soil agglomeration, conducive to maintaining water and soil. The improved biodiversity also increased the water and fertility retention of the soil (Bestelmeyer et al. 2006; Han et al. 2008; Su et al. 2007).

Figure 8 taken by Lei Jiang,obtained the permission of Jiang Lei

Conclusions

The Artificial Tamarix Chinensis forest could decompose and reduce the content of sand in the soil, and thereby increase the content of clay and powder. The sand content was decreased and the clay and powder contents were increased with the increase of the soil depth.

From the determination of a series of chemical substances, such as the organic matter, organic carbon, N, P and K, the Artificial Tamarix Chinensis forest could increase their contents and therefore the soil fertility. There is a trend of content decreasing with the increase of the soil depth.

As to the monitoring of the regional microclimate, the artificial Tamarix Chinensis forests at different test sites could significantly reduce the daily temperature and relative humidity ranges and effectively reduce the wind speed in April and August. The protection and regulation performance of the Artificial Tamarix Chinensis forests was significantly better in August than in April.

The ecology restoration project with the Artificial Tamarix-Cistanche increased the local biodiversity, especially at the test sites with significantly enlarged coverage.

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Declarations

Compliance with ethical standards: This manuscript complies with ethical standards and ethics,agree to publish.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical statement The work has not been published previously and is not under consideration for publication elsewhere.

Authors' contributions:

This manuscript is mainly completed by Lei Jiang · Ying Wang · Liang he · Zi Yong Sun · Yunde Liu · Jiang Wei bu. Ying Wang is responsible for reviewing and submitting the manuscript, and Lei Jiang is responsible for searching materials and writing articles.All authors read and approved the final manuscript.

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Figures

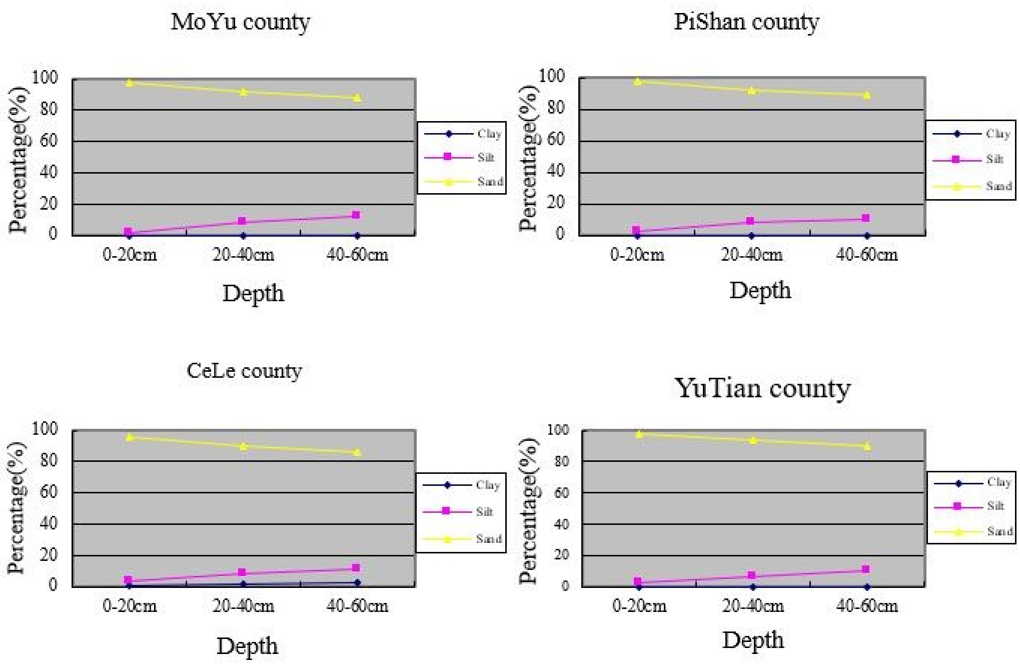

Figure 1

Vertical distribution of soil particle size in different experimental areas Fig 1 twas made by Lei Jiang obtained the permission of Jiang Lei

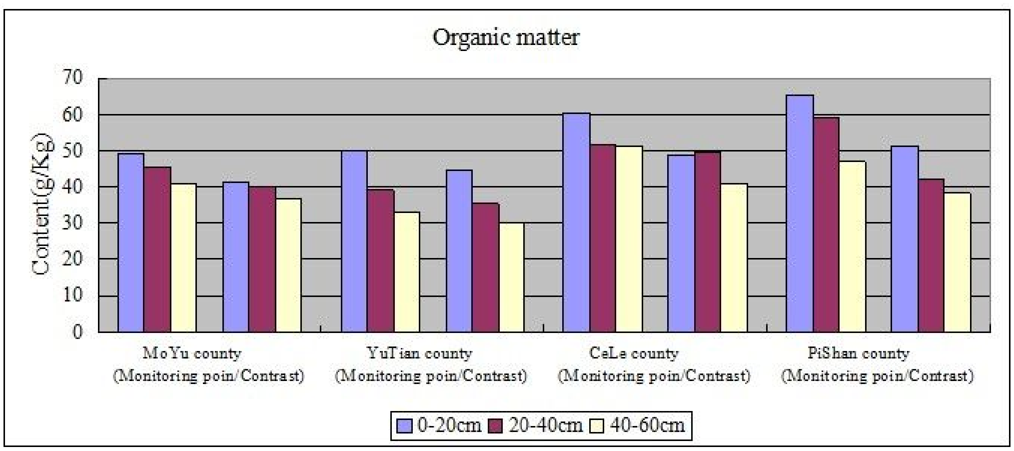

Figure 2

Vertical distribution of soil organic matter in different experimental areas Fig 2 twas made by Lei Jiang obtained the permission of Jiang Lei

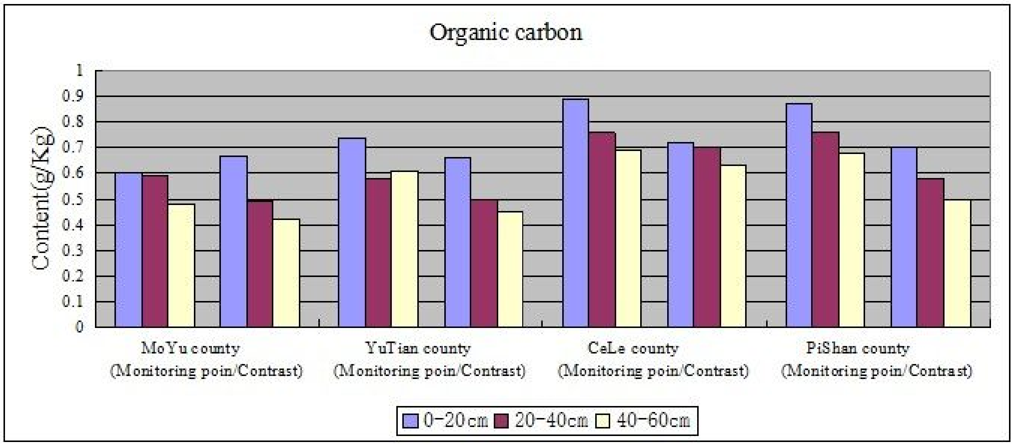

Figure 3

Vertical distribution of soil organic carbon in different experimental areas Fig 3 twas made by Lei Jiang，obtained the permission of Jiang Lei

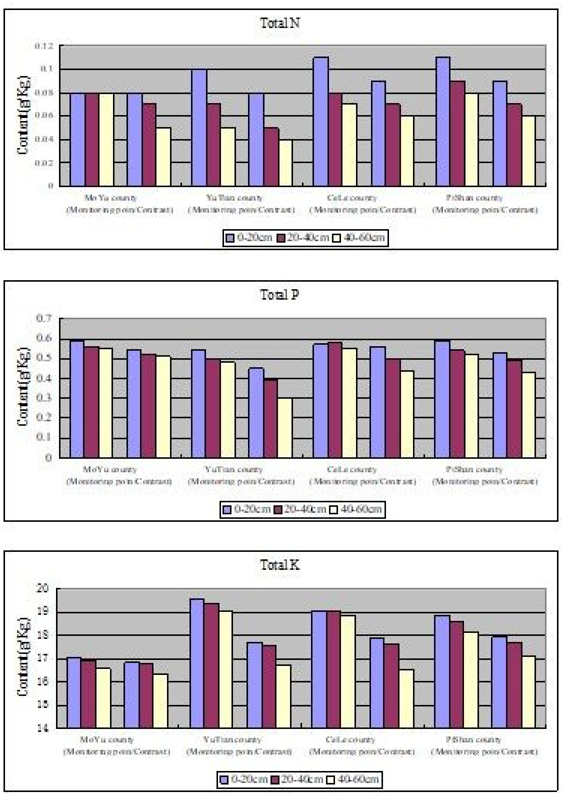

Figure 4

Vertical distribution of soil total N, P and K in different experimental areas Fig 4 twas made by Lei Jiang，obtained the permission of Jiang Lei

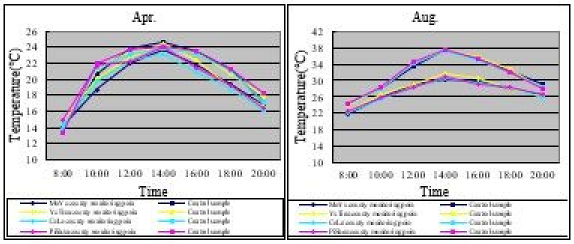

Figure 5

Diurnal temperature variation during April and August in different experimental areas Fig 5 twas made by Lei Jiang，obtained the permission of Jiang Lei

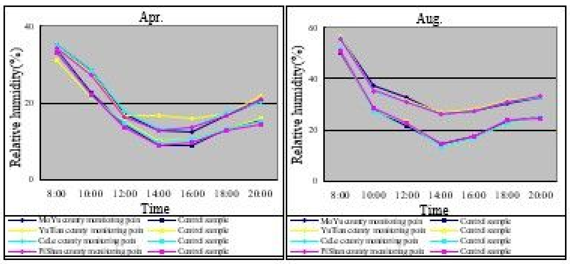

Figure 6

Diurnal relative humidity variation during April and August in different experimental areas Fig 6 twas made by Lei Jiang，obtained the permission of Jiang Lei

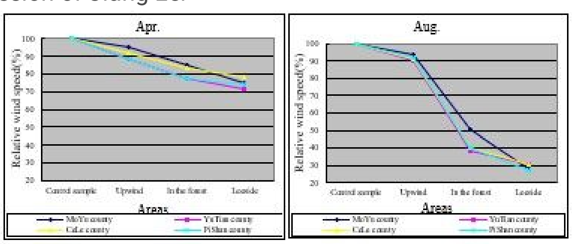

Figure 7

Change of relative wind speed during April and August in different experimental areas Fig 7 twas made by Lei Jiang，obtained the permission of Jiang Lei

Figure 8

The situation of plant growth in experimental areas Fig 8 taken by Lei Jiang，obtained the permission of Jiang Lei