Introduction on Soil Erosion Fighting Test of High-Quality American Forage Grass

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Abstract: With the rapid and continuous economic growth in China, there is increased demand for improved forage-livestock systems and improved environmental protection including soil erosion control. The Three Gorges Project has increased concern related to soil erosion and sedimentation throughout the Yangtze (Changjiang) River watershed. There is a desire to develop comprehensive sustainable solutions to these problems. Part of these sustainable solutions will involve the planting of grasses and legumes to reduce soil erosion and provide forage for livestock in multiple use systems. In cooperation with Oragon Seed Council (OSC), the Yangtze soil and water conservation bureau, initiated a project aiming at testing production and soil erosion fighting capability of selected US 7 forage species from Oct., 2001. The point of this paper is to illustrate the whole process when testing, as well as discussing the performance comparison of each species. As a conclusion, such forages and legumes as perennial ryegrass and bentgrass were distinguished in greatly improving land cover, high production and better palatability to goats, thus could be adopted in soil conservation practices and forest recovery in steep-sloped farmland.

The forage grass planting can tackle the problem of "fertilizer, chaff and fuel", promote the development of livestock farming, poultry and fishery and readjust the industrial set-up. On the other hand, the planting is an economic and efficient water and soil conservation measure to prevent water and soil loss and improve ecological environment. The test plot is located in the area with complicated geomorphology, sparse vegetation, weak ecological environment, loose surface structure, low erosion resistance and serious water and soil loss. The water and soil loss area accounts for 54.3% of the reservoir area, which is listed as one of the key areas of water and soil conservation in the middle and lower reaches of Yangtze River.

In order to improve the ecological environment of the Three Gorges reservoir, develop the livestock farming and speed up the of poverty relief, the Water & Soil Bureau of Yiling District (Yichang City, Hubei Province), cooperating with Oregon (America) Grass Seed Society, performed the test for the purpose of finding out the adaptability of high-quality forage grass from America in the reservoir area and the comprehensive effectiveness in water and soil conservation.

1 Description of test plot

The test plot is located in two villages (Shiban and Huaji) of Sandouping County, with an area of 1.2hm^2, average sea level of 225m and slope of 35—45 degrees.

The area belongs to typical low relief terrain of strong-weathered granite, with the behaviors of developed bedding, loose structure and soft strata. The overburden (20cm—70cm thick, pH value = 6—6.5) belongs to sandy loam due to exposed mother rock with good air permeability and bad water retention.

The area is situated in the typical subtropical monsoon climate zone where is suitable for the growth of various grasses. The air temperature of the area is ranged within –1.5℃—39℃. The statistics of years for the climate include 1,838.8 hours of sunshine, 1,100mm—1,500mm of annual rainfall (rainfall in June to September accounting for 58.6% of the whole year) and 290 days of frost-free period.

2 Test items

As the above-mentioned, the area is suitable for the growth of forage grass. In the plot, tests have been performed for three targets. Test I is repeated test for adaptability, consisting of 3 groups, 7 strips for

each group with 20m long and 5m wide, namely 1 test and 2 repeats. The test composition includes:

(1) White clover + Bermuda grass

(2) White clover + fall fescue

(3) White clover + colonial bentgrass

(4) White clover + orchard grass

(5) White clover + perennial ryegrass

(6) White clover + bahia grass

(7) White clover + alfalra

Test II is carried out between forestland and grassland with 2 groups, 9 strips and 0.66 hm^2 of test area.

(1) White clover + fall fescue with 5 strips

(2) White clover + Bermuda grass with 4 strips

3 Test methods

Through simple comparison test of fields, the improved breeds suitable for local growth conditions are selected. The test period is of 1 year, namely from September 2000 to August 2001. After sowing, the emergence, growth and grass output had been observed and the rainfall, sand and runoff amount had been measured. The weeding was carried out in time and topdressing was also conducted timely and quantitatively. The observation during phonological period was performed every 15 days while measuring the growth height. In accordance with the covering rate of sample and the quantities of tiller, grass cutting (at its certain height), fresh and dry (after weathered) grass weighing, calculation of its water content and ratio and estimate of its per mu yield were performed. From the comparative analysis of sand and runoff, the effect of forage grass planting on water and soil conservation was found out.

It is in the autumn to sow for the forage grass in the test. Before sowing, the test ground was ploughed shallow and racked and separated according to the test requirements to ensure the grass of every strip unmixed.

4 Grass growing in test base

4.1 Standard test plot

The standard test plot was commenced on August 21 and sowed on September 29 with total area of 0.15 hm^2, consisting of 8 strips. Each strip is 20m long and 5m wide with direction of east-to-west and slope of 43.5 degrees.

(1) White clover + Bermuda grass

Sowing began on September 29. White clover and Bermuda grass sprouted respectively on October 2 and 10 with germination percentage of 12%. Re-sowing was conducted on March 19 with soil layer for growth of 20cm—50cm thick, but the germination percentage was still very low. This kind of forage grass grew bad with the maximum height of 210mm and per mu[1] yield of only 175.7kg. It was found through preliminary analysis that, the thin soil and insufficient fertility might be the objective reasons influencing the growth of grass, and maybe it was not suitable for Bermuda grass to sow in autumn.

(2) White clover + fall fescue

Sowing began on September 29. White clover and fall fescue came up respectively on October 2 and 6 with germination percentage of 60%. The soil layer for growth was of 50cm—70cm thick. The grass grew well with the maximum height of 560mm and per mu yield of 2,702.41kg.

(3) White clover + colonial bentgrass

Sowing began on September 29. White clover and colonial bentgrass came up respectively on October 2 and 5 with germination percentage of 85%. The soil layer for growth was of 50cm—70cm thick. The grass grew well with the maximum height of 550mm and per mu yield of 3,654.2kg.

[1] 1 mu = 1/15 hm^2

(4) Abandoned land (without vegetation cover)

(5) White clover + orchard grass

Sowing began on September 29. White clover and orchard grass came up respectively on October 2 and 5 with germination percentage of 60%. The soil layer for growth was of 15cm—20cm thick. The grass grew well with the maximum height of 550mm and per mu yield of 2,352.6kg.

(6) White clover + perennial ryegrass

Sowing began on September 29. White clover and perennial ryegrass came up respectively on October 2 and 5 with germination percentage of 20%. The soil layer for growth was of 20cm—40cm thick. The grass grew well with the maximum height of 540mm and per mu yield of 886.1kg. For the low percentage of germination, it was thought that something wrong with the seeds or maybe it was not suitable for the grass to sow in autumn through preliminary analysis.

(7) White clover + bahia grass

Sowing began on September 29. White clover and bahia grass came up respectively on October 2 and 5 with germination percentage of 15%. The soil layer for growth was of 15cm—30cm thick. The grass grew well with the maximum height of 900mm and per mu yield of 875.1kg. For the low percentage of germination, it was thought that something wrong with the seeds or maybe it was not suitable for the grass to sow in autumn through preliminary analysis.

(8) White clover + alfalfa

Sowing began on September 29. White clover and alfalfa came up respectively on October 2 and 5 with germination percentage of 50%. The soil layer for growth was of 20cm—30cm thick. The grass grew well with the maximum height of 530mm and per mu yield of 1,810.6kg.

4.2 Repeated test Ⅱ plot

The repeated test Ⅱ plot is the first repeated test-plot, covering an area of 0.2hm^2 with 7strips. Each strip is of 20m long and 5m wide with its direction of east-to-west and slope of 35 degrees. The plot is characterized with adequate water sources and fertile soil layers. Sowing began on October 3.

(1) White clover + Bermuda grass

Sowing began on October 3. White clover and Bermuda grass came up respectively on October 6 and 10 with low germination percentage of 15%. The soil layer for growth was of 20cm—40cm thick. The grass grew bad with the maximum height of 306mm and per mu yield of 238.3kg.

(2) White clover + fall fescue

Sowing began on October 3. White clover and fall fescue came up respectively on October 6 and 10 with germination percentage of 65%. The soil layer for growth was of 30cm—50cm thick. The grass grew well with the maximum height of 560mm and per mu yield of 3,623.9kg.

(3) White clover + colonial bentgrass

Sowing began on October 3. White clover and colonial bentgrass came up respectively on October 6 and 10 with germination percentage of 90%. The soil layer for growth was of 50cm—60cm thick. The grass grew well with the maximum height of 580mm and per mu yield of 3,878.2kg.

(4) White clover + orchard grass

Sowing began on October 3. White clover and orchard grass came up respectively on October 6 and 10 with germination percentage of 65%. The soil layer for growth was of 20cm—40cm thick. The grass grew well with the maximum height of 577mm and per mu yield of 3,072kg.

(5) White clover + perennial ryegrass

Sowing began on October 3. White clover and perennial ryegrass came up respectively on October 6 and 10 with low germination percentage of 30%. The soil layer for growth was of 20cm—50cm thick. The grass grew well with the maximum height of 680mm and per mu yield of 1,057.7kg.

(6) White clover + bahia grass

Sowing began on October 3. White clover and fall bahia grass came up respectively on October 6 and 10 with low germination percentage of 20%. The soil layer for growth was of 30cm—50cm thick. The grass grew well with the maximum height of 944mm and per mu yield of 795.9kg.

(7) White clover + alfalfa

Sowing began on October 3. White clover and alfalra came up respectively on October 6 and 10 with

germination percentage of 55%. The soil layer for growth was of 50cm—70cm thick. The grass grew well with the maximum height of 781mm and per mu yield of 1,943.7kg.

4.3 Repeated test Ⅲ plot

The repeated test Ⅲ plot is the second repeated test-plot, covering an area of 0.2hm^2 with 7strips. Each strip is of 20m long and 5m wide with its direction of south-to-north and slope of 45 degrees. The soil layer is of 15—30 thick. Sowing began on October 3.

(1) White clover + Bermuda grass

Sowing began on October 3. White clover and Bermuda grass came up respectively on October 6 and 12 with low germination percentage of 10%. The soil layer for growth was of 20cm—30cm thick. The grass grew bad with the maximum height of 186mm and per mu yield of 142.9kg.

(2) White clover + fall fescue

Sowing began on October 3. White clover and fall fescue came up respectively on October 6 and 12 with germination percentage of 50%. The soil layer for growth was of 15cm—20cm thick. The grass grew well with the maximum height of 458mm and per mu yield of 1,078.7kg.

(3) White clover + colonial bentgrass

Sowing began on October 3. White clover and colonial bentgrass came up respectively on October 6 and 12 with germination percentage of 75%. The soil layer for growth was of 15cm—20cm thick. The grass grew well with the maximum height of 465mm and per mu yield of 1,484.3kg.

(4) White clover + orchard grass

Sowing began on October 3. White clover and orchard grass came up respectively on October 6 and 12 with germination percentage of 50%. The soil layer for growth was of 20cm—30cm thick. The grass grew well with the maximum height of 472mm and per mu yield of 829.7kg.

(5) White clover + perennial ryegrass

Sowing began on October 3. White clover and perennial ryegrass came up respectively on October 6 and 12 with low germination percentage of 15%. The soil layer for growth was of 15cm—20cm thick. The grass grew commonly with the maximum height of 562mm and per mu yield of 462.1kg.

(6) White clover + bahia grass

Sowing began on October 3. White clover and bahia grass came up respectively on October 6 and 12 with low germination percentage of 15%. The soil layer for growth was of 15cm—30cm thick. The grass grew commonly with the maximum height of 667mm and per mu yield of 219.1kg.

(7) White clover + alfalfa

Sowing began on October 3. White clover and alfalfa came up respectively on October 6 and 12 with germination percentage of 40%. The soil layer for growth was of 15cm—20cm thick. The grass grew commonly with the maximum height of 527mm and per mu yield of 577kg.

4.4 Test area arranged in forestland and grassland

The test area arranged in forestland and grassland consists of 9 test plots with total area of 0.45hm^2, accounting for 2/3 of the total area. No.1, 2 and 9 plots run from east to west and No.3, 4, 5, 6, 7 plots run from south to north with a slope of 40 degrees and soil layer for growth of 20cm—50cm thick. Sowing began on October 3 under the original geomorphic conditions for white clover + Bermuda grass and white clover + fall fescue.

(1) White clover + Bermuda grass (in No.2, 4, 6, 8 plots)

Sowing began on October 3. White clover and Bermuda grass came up respectively on October 6 and 15 with low germination percentage of only 5%. The soil layer for growth was of 20cm—50cm thick. The grass grew bad with the maximum height of 662mm and the minimum of 390mm and per mu yield of 127kg—179kg.

(2) White clover + fall fescue (in No.1, 3, 5, 7, 9 plots)

Sowing began on October 3. White clover and fall fescue came up respectively on October 6 and 15 with germination percentage of 50%. The soil layer for growth was of 20cm—50cm thick. The grass

grew commonly with the maximum height of 821mm and the minimum of 590mm and per mu yield of 1,280.81—1,880.1kg.

4.5 Test area of ryegrass

The test area of ryegrass is adjacent and lower of the standard test plot with an area of 0.2hm^2. The area consists of 8 test plots with the slope direction of east-to-west and a slope of 45 degrees.

Sowing began on October 5. The grass came up on October 15 and with germination percentage of 80%. The soil layer for growth was of 40cm—60cm thick. The grass grew well with the maximum height of 1,210mm and per mu yield of 2,848.3kg because of its good adaptability, developed root system and much more tillers.

5 Forage grass growth analysis of test area

5.1 Repeated test area

(1) White clover + Bermuda grass

For this kind of grass, its germination percentage was lower no matter how the soil quality of the 3 repeated test areas was. Re-sowing was performed on March 19, but the germination percentage was still very low (the maximum of 15% and only part of the Bermuda grass sprouted till July 14). Through preliminary analysis, it was thought that sowing was not suitable in spring and autumn. It was suggested that the sowing should be carried out in summer due to concentrated rainfall and great water content that time. In addition, the forage grass was not adaptable to the local conditions because of its worse growth.

(2) White clover + fall fescue

In the 3 test plots, the germination percentage of this kind of grass was higher with the maximum of 65% and better growth due to adequate water, fertilizer and sunshine. The grass in test Ⅱ plot grew best with the per mu yield of 3,623.9kg because of fertile soil there.

(3) White clover + colonial bentgrass

In the 3 test plots, the germination percentage of this kind of grass was highest with the maximum of 85% and better growth. Due to the fertile soil, adequate water and sunshine, the grass in repeated test Ⅱ plot grew best; while due to the poor and dry soil of the standard test plot and repeated test Ⅲ plot, the grass grew worse. The grass grew with the maximum height of 580mm and the per mu yield of 3,878.2kg. It is worth developing and spreading in the area.

(4) White clover +orchard grass

The germination percentage of the grass could reach 65% and the grass grew well. Especially, the grass in repeated test Ⅱ plot grew best with the maximum height of 577mm and the per mu yield of 3,072kg. It is worth developing and spreading in the area.

(5) White clover +perennial ryegrass

The germination percentage of the grass was lower only with the maximum of 30% and better growth. It was thought through preliminary analysis that the lower germination percentage was caused by seed itself and maybe it was not suitable for the grass to sow in autumn. It was found through comparison test of the 3 plots, the grass in repeated test Ⅱ plot grew best with the maximum height of 680mm and the per mu yield of 1,057.7kg. It is suitable to the local conditions.

(6) White clover + bahia grass

The germination percentage of the grass was lower with the maximum of 20% and better growth. It was thought through preliminary analysis that something was wrong with the seed and maybe it was not appropriate for the grass to sow in autumn. In order to improve the rate of emergence, the sowing time should be changed properly. Among the 3 plots the grass in repeated test Ⅱ plot grew best with the maximum height of 944mm and the per mu yield of 795.9kg. Therefore, it is worth developing and spreading in the area.

(7) White clover + alfalfa

The germination percentage of the grass was moderate with the maximum of 55% and the better growth. Through comparison test of the 3 plots, the grass in repeated test Ⅱ plot grew best due to the

fertile soil and full sunshine, with the maximum height of 781mm and the per mu yield of 1,943.7kg. Therefore it is also worth developing and spreading in the area.

It can be seen from the comparison tests of the 3 plots, the grass in repeated test Ⅱ plot grow best due to the favorable conditions in soil, water, fertility and sunshine; and for the same strip, due to the big slope, the water, soil and fertilizer move from upper part to down part under the influence of water and soil loss, the grass of down part grows better than that of upper part. For standard test plot, the fertility of top soil is eroded, so the grass grows worse; but in the course of growth, a little amount of urea is applied, so the grass grows better than that in repeated test Ⅲ plot but worse than that in repeated test Ⅱ plot. The grass in repeated test Ⅲ plot grows worse due to the thin soil and insufficient fertility and without applying fertilizer. Thus it can be seen that, soil and fertility are the base on which the grass depends for growth, and the fertility affects the growth of grass directly. In the 3 test plots, wherever the Bermuda grass and bahia grass are, the germination percentage is lower, and the bahia grass grows well, it may be related to the sowing time and seed. In order to improve the rate of emergence, the sowing time for bahia grass shall be adjusted properly. The fall fescue, colonial bentgrass and orchard grass grow better wherever they are, and the germination percentage is higher, because it was raining when sowing seeds, the adequate rainfall and appropriate temperature were favorable to seed sprouting. The bahia grass, fall fescue, colonial bentgrass and orchard grass possess strong reproducibility, they can reproduce quickly after mowing.

5.2 Test area of ryegrass system

The test area is composed of 8 strips, the cross tests of 6 varieties have been carried out. The germination percentage reaches 60%, the grass grow better with the maximum height of 1.0m—1.3m, and per mu yield reaches 2,848.3kg. The ryegrass is high in quality with the characteristics of developed root system, shallow distribution of root system and much more tillers. The grass possesses strong reproducibility and can reproduce quickly after mowing. In general, the grass can be mowed 3—5 times a year, and in order to accelerate the reproduction of ryegrass, a certain amount of nitrogenous fertilizer shall be applied before mowing and more than 50mm stubble shall be left. The grass is in the ear in May, and 15kg—30kg seeds can be gained per mu due to its strong wild nature. Keeping moisture of soil and providing sufficient nutrient especially the nitrogenous fertilizer during growing season will helpful to the increase of yield. With strong adaptability, the ryegrass is worth developing and spreading in the area.

5.3 Test in forestland and grassland

(1) White clover + Bermuda grass

In the comparison test of 4 strips, the germination percentage was only 5% and the grass grew worse. Even though re-sowing was performed on March 19, the germination percentage was still lower. Therefore the grass is not suitable to the local soil and climate conditions.

(2) White clover + fall fescue

Through comparative analysis of 5 strips, the grass grew better and the germination percentage reached 50%. The grass possessed strong reproducibility and grew again quickly after mowing if a certain urea was applied before mowing. Firstly, in the 7th strip near water source, with thick soil and fertile soil, the fall fescue grew to 590mm high and the per mu yield reached 1,880.1kg. Secondly, in the 9th strip exposed to the sun, the fall fescue grew to 486mm high and the per mu yield reached 1,525.9kg due to the full sunshine and fertile soil. Thirdly, in the 1st strip down of standard test plot, the fall fescue grew to 410mm high and the per mu yield reached 1,395kg due to the thick and fertile soil coming from standard test plot. Finally in the 4th strip, the fall fescue grew worst due to the poor and thin soil and insufficient fertility, with the maximum height of only 340mm and the per mu yield of 1,285.4kg. Thus it can be seen, in the place with thicker and more fertile soil, the grass grows better; in the place near water source, the more developed the root is, the bigger the leaves are and the more luxuriantly the grass is. The grass exposed to the sun grew better than that in a poor light. Namely, only fine nature conditions (temperature, moisture, sunshine, fertilizer and soil quality) can provide better living environment for the grass. In

general, the fall fescue grows better and is suitable to the local soil and climate conditions and is worth developing and spreading.

6 Benefit analysis of water and soil conservation of test base

The high-quality forage grassland is luxuriant in branches and leaves. The developed root system plays the role of rainfall interception, runoff detention, soil consolidation, moisture preservation of soil, soil improvement and erosion control. The shaded layer with forage grass prevents the ground from striking of storm. Through physical, chemical and biologic action, the dead leaves and root system can be helpful to the improvement of topsoil structure, the increase of pore, the acceleration of surface water infiltrating into deep soil, the control of water and soil loss, and the improvement of water and soil conservation benefit.

On the slope (43.5º) with the same soil conditions, 5 simply-built runoff plots totaling 100m^2 and a 3m^3 engrafted basin enclosed with 3m high brick wall in 3 sides was arranged in the down of the plots. The Bermuda grass, fall fescue, colonial bentgrass and orchard grass were cropped continuously in the plots separately and then compared with that in the abandoned land. For these grasses, no fertilizer was applied, and the management method is the same as that for field crops. In this study, the method of plotting position was applied, namely, to measure the runoff and sediment yield after storm, to take mixed sediment sample for filtration, then to measure the sediment content, finally to analyze the impact of the 4 kinds of grasses on soil moisture, water and soil loss, and storm interception.

Following tables give the benefit analysis of water and soil conservation of 4 kinds of grasses under different rainfall conditions.

Table 1 Comparison of runoff and sediment in different forage grass plots on June 17 of 2001

Grass	Coverage of sample plot (%)	Rainfall (mm)	Gage reading (mm)	Runoff amount (m^3)	Runoff depth (mm)	Sediment amount (kg)	Erosion modulus (kg/m^2)	Soil erosion (t/m^2)
Bermuda	30	33.5	198	0.49	4.9	105.53	1.05	1,050
Fall fescue	80	33.5	169	0.41	4.1	70.71	0.707	707
Colonial bentgrass	81	33.5	147	0.34	3.4	60.21	0.6	600
Orchard	62	33.5	158	0.37	3.7	70.39	0.704	704
Abandoned land	10	33.5	199	0.49	4.9	113.26	1.132	1,132
Remarks	Basin volume of 3m^3, water sample volume of 1,000ml and sample plot area of 100m^2							

Table 2 Comparison of runoff and sediment in different forage grass plots on June 28 of 2001

Grass	Coverage of sample plot (%)	Rainfall (mm)	Gage reading (mm)	Runoff amount (m^3)	Runoff depth (mm)	Sediment amount (kg)	Erosion modulus (kg/m^2)	Soil erosion (t/m^2)
Bermuda	30	46.6	188	0.42	4.2	96.73	0.967	967
Fall fescue	82	46.6	179	0.4	4.0	87.91	0.879	879
Colonial bentgrass	87	46.6	168	0.36	3.6	83.56	0.835	835
Orchard	63	46.6	172	0.37	3.7	86.64	0.866	866
Abandoned land	10	46.6	199	0.45	4.5	112.58	1.125	1125
Remarks	Basin volume of 3m^3, water sample volume of 1,000ml and sample plot area of 100m^2							

Table 3 Comparison of runoff and sediment in different forage grass plots on July 2 of 2001

Grass	Coverage of sample plot (%)	Rainfall (mm)	Gage reading (mm)	Runoff amount (m^3)	Runoff depth (mm)	Sediment amount (kg)	Erosion modulus (kg/m^2)	Soil erosion (t/m^2)
Bermuda	35	25.2	127	0.31	3.1	61.08	0.61	610
Fall fescue	82	25.2	104	0.23	2.3	34	0.34	340
Colonial bentgrass	87	25.2	102	0.23	2.3	32.43	0.324	324
Orchard	63	25.2	104	0.23	2.3	33.38	0.334	334
Abandoned land	10	25.2	129	0.31	3.1	61.21	0.612	612
Remarks	Basin volume of $3m^3$, water sample volume of 1,000ml and sample plot area of $100m^2$							

Table 4 Comparison of runoff and sediment in different forage grass plots on July 27 of 2001

Grass	Coverage of sample plot (%)	Rainfall (mm)	Gage reading (mm)	Runoff amount (m^3)	Runoff depth (mm)	Sediment amount (kg)	Erosion modulus (kg/m^2)	Soil erosion (t/m^2)
Bermuda	35	22.2	131	0.33	3.3	61.08	0.61	610
Fall fescue	82	22.2	117	0.28	2.8	44.3	0.443	443
Colonial bentgrass	87	22.2	119	0.29	2.9	41.08	0.41	410
Orchard	63	22.2	121	0.29	2.9	42.2	0.422	422
Abandoned land	20	22.2	133	0.33	3.3	65.62	0.656	656
Remarks	Basin volume of $3m^3$, water sample volume of 1,000ml and sample plot area of $100m^2$							

Table 5 Comparison of runoff and sediment in different forage grass plots on July 29 of 2001

Grass	Coverage of sample plot (%)	Rainfall (mm)	Gage reading (mm)	Runoff amount (m^3)	Runoff depth (mm)	Sediment amount (kg)	Erosion modulus (kg/m^2)	Soil erosion (t/m^2)
Bermuda	35	43.9	207	0.49	4.9	120.81	1.2	1,200
Fall fescue	82	43.9	206	0.48	4.8	86.63	0.866	866
Colonial bentgrass	87	43.9	205	0.48	4.8	78.82	0.788	788
Orchard	63	43.9	204	0.48	4.8	79.50	0.795	792
Abandoned land	20	43.9	211	0.5	5.0	130.95	1.309	1,309
Remarks	Basin volume of $3m^3$, water sample volume of 1,000ml and sample plot area of $100m^2$							

Water and soil are the base on which human beings rely for existence, water and soil conservation and erosion loss control are the basic national policy that we shall adhere to for a long term. The functions of forage grass in water reducing for soil conservation show: the concentrated vegetation covering the ground, the root system making the soil consolidated and the infiltration rate increased. Therefore, the mud interception and water storage effects of forage grass are closely related to its coverage, the higher the coverage is, the more notable the water and soil conservation benefit is.

Table 6 Comparison of runoff and sediment in different forage grass plots on July 30 of 2001

Grass	Coverage of sample plot (%)	Rainfall (mm)	Gage reading (mm)	Runoff amount (m^3)	Runoff depth (mm)	Sediment amount (kg)	Erosion modulus (kg/m^2)	Soil erosion (t/m^2)
Bermuda	35	61.9	266	0.61	6.1	195.03	1.95	1,950
Fall fescue	82	61.9	253	0.57	5.7	173.6	1.736	1,736
Colonial bentgrass	87	61.9	246	0.55	5.5	148.17	1.482	1,482
Orchard	63	61.9	251	0.56	5.6	157.7	1.577	1,577
Abandoned land	20	61.9	277	0.64	6.4	208.78	2.088	2,088
Remarks	Basin volume of $3m^3$, water sample volume of 1,000ml and sample plot area of $100m^2$							

It can be seen from tables: during storm period the sediment loss of forage grass land is less than the exposed land without vegetation, and the sediment loss of forage grass land with higher cover degree is less than that with lower cover degree, which means the 4 kinds of forage grasses taking an important role in mud interception, water storage and soil loss control. Through comparison of the 4 forage grasses, the white clover + colonial bentgrass possesses the best benefit in rainfall interception and soil erosion control, the white clover + orchard grass comes second, the white clover + fall fescue takes third place, and the white clover + Bermuda grass takes last place. For the land planted with white clover + colonial bentgrass, white clover + fall fescue, white clover + orchard grass and white clover + Bermuda grass, the annual runoff can be reduced for 17.6%, 13.1%, 14.3%, 3.6% respectively, and the annual soil erosion ratio can be reduced for 35.9%, 28.2%, 32.1%, and 7.8% correspondingly. Among them the water and soil conservation benefit of the white clover + colonial bentgrass takes first place.

The physiological metabolism of plant can result in the reduction of soil moisture, but root system of plant and vegetation can make the physicochemical behaviors of soil improved, force the rainfall infiltrating in soil, reduce the runoff and increase the soil moisture. The two actions interfere with each other to bring about new change of soil moisture. Through analysis and observation, the amplitudes of soil moisture variation for 4 grasses are shown as: white clover + Bermuda grass > white clover + fall fescue > white clover + orchard grass > white clover + colonial bentgrass. During storm period, the increment of soil moisture for white clover + colonial bentgrass is the highest one, while is the lowest for white clover + Bermuda grass. The 4 kinds of grasses can keep a large amount of rainfall in soil, reduce the surface runoff, and control the water and soil loss effectively.

7 Conclusions

The key of forage grass planting lies in the sowing time and field management in order to gain higher germination percentage. The sowing shall be carried out in opportune time according to the local climate conditions. In field management, the stress shall be put on weed elimination and soil moisture preservation. In addition, the tillage shall be cleaned for 3—4 times during seedling period to eliminate the harmfulness of weed and guarantee the survival rate of forage grass. At the same time, the soil shall be loosened to improve the infiltration capacity and prevent moisture vaporizing, especially in severe drought season.

During growth period and before mowing of forage grass, topdressing shall be performed properly to guarantee the fine growth state and increase the output.

The introduced high-quality American forage grass can form a coverage layer quickly in the process of growth, thus entrapping the continuous runoff, reducing the water and soil loss, strengthening the soil fertility, increasing the water content of soil and improving the ecologic environment of the Three Gorges reservoir area greatly, and also promoting the change of the agricultural and industrial structure, the development of livestock farming and the increase of peasants' income.

Through test, the fall fescue, orchard grass, alfalfa, colonial bentgrass and ryegrass suitable for the conditions of the Three Gorges reservoir area are selected. They can grow normally with high yield even under the conditions of non-irrigation and severe drought. If 2—3 times irrigation a year can be performed and fertility can be strengthened properly, it is hopeful to achieve higher yield.

For the Bermuda grass, it is not suitable to local climate and environment as its lower germination percentage; the coverage layer is not formed quickly during growth period, thus resulting in serious water and soil loss.

In this summer, an exceptionally serious drought happened in the district, the introduced forage grasses did not die of drought except leaf roll happened. According to the characteristics, it is suggested to popularize the forage grasses in low-yield land, derelict land and thin sandy ground, so as to establish reliable forage base to promote the development of livestock forming, and also to improve the local ecological environment, enlarge the environmental capability for migrant resettlement and shake off poverty completely.