Hydrol. Earth Syst. Sci. Discuss., 8, C732–C748, 2011
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Hydrology and Earth System Sciences Discussions

Interactive comment on "Hydrologic feasibility of artificial forestation in the semi-arid Loess Plateau of China" *by* T. T. Jin et al.

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jintiantian05@mails.gucas.ac.cn

Received and published: 2 April 2011

First of all we would like to thank Anonymous Referee #3 for his insightful comments and detailed suggestions on our manuscript. Our replies are as follow:

Q: General comments: In my opinion, this is an interesting paper that investigates the major factors controlling large scale spatial variability in soil water content in afforested areas of the Loess Plateau (China). The paper focuses on two spatial scales: regional scale (a transect across a large latitudinal and rainfall gradient spanning 300 kms) and watershed scale (three separate watersheds with very different precipitation amount). The data presented here are interesting, and the major conclusions of the paper are probably correct. However, my major concern with this study is the authors' decision to emphasize and focus on the relationships between soil moisture content and environmental parameters at the regional scale, rather than the watershed scale (much more relevant and interesting in my opinion). At the regional scale, latitude and total annual rainfall amount (ranging from 352 to 617 mm) are by far the major factors determining spatial variations in soil moisture content (SMC, e.g. see fig 7), thus overshadowing and obscuring the roles of other parameters (stand density, stand age, aspect, soil organic matter content, percent herbaceous cover, slope, tree height and diameter, etc). Since the strong positive relationship between rainfall amount and soil moisture across large geographical and climatic gradients is pretty obvious and not terribly interesting, I would strongly advice the authors to focus the paper instead on the watershed scale. I suggest to analyse the relationships between SMC and all the above mentioned environmental parameters (stand density, etc) separately for each watershed. I would emphasize the differences and similarities between watersheds in the relationships between environmental parameters (stand density, etc) and SMC, and would then discuss the role that total annual precipitation may have in modulating these relationships.

Reply: We will revise the paper and put more emphasis on SMC variation in different watershed. In latitudinal gradient, the strong effect of rainfall on SMC and other parameters (stand density, stand age, percent herbaceous cover) may obscure the roles of other parameters. This has been involved in our manuscript. Perhaps the formulation wasn't exact. We will correct the improper formulation and adjust the structure of the manuscript.

Q: Also, I recommend that the paper is revised by a native English speaker for the sake of clarity and readability.

Reply: the revised paper will be revised by a native English speaker again before submission.

Specific comments:

P656, L12: the difference between "neglectable" and "non-apparent" is not very clear to me, please reword.

Reply: In the manuscript, we used “neglectable” and “non-apparent” to express “tiny” and “undetectable”. We have changed them in the manuscript.

P657, L8-9: How uniform is soil texture across the latitudinal gradient? And how uniform is it within watersheds? This is an important consideration for the interpretation of SMC data (e.g. the authors recognize that soils are sandier at the northern end of the regional gradient). It would be very helpful if the authors could provide detailed soil texture data for the different watersheds.

Reply: We didn’t measure soil texture in this study. From experience of other researchers, soil texture in the Loess Plateau is quite uniform. Therefore we hypothesize that soil texture in our study is uniform with a little change. Herewith, we will cite soil texture data (watershed scale: Yangjuan watershed; Regional scale: four countries in the study area. Refer to supplement figure 1 for these locations) from literatures to support our hypothesis. Supplement table 1 give out the soil texture classification standards in China.

Soil texture across the latitudinal gradient:

Across the latitudinal gradient, the composition of soil particles from four countries in the northern Shaanxi Province (the four countries can represent the latitudinal gradient covered in our study. Please refer to supplement figure 1 for their locations) were shown in the supplement figure 2. Coarse silt made up more than 55% of the soil particles in four countries. Sand percentage (including fine sand and coarse sand) in Huangling, Yichuan, and Yanchuan were 10.6, 12.1, and 14.6 respectivly, and soil in these countries can be classified to sandy silt (supplement table 1). Sand percentage in Mizhi was 22.0%, and soil in this country can be classified to silt. Though aggregate may change modest across the latitudinal gradient, soil texture is uniform highly across the latitudinal gradient (Zhang, 2002). From the south to the north, the percentage of fine sand and coarse silt increases; the percentage of medium silt, fine silt, and clay decreases (supplement figure 2). That is to say soil in the north is sandier.

Soil texture within watershed scale:

To reveal how uniform soil texture is within watershed, we exhibited data from Yangjuan watershed in the North of Shaanxi Province. Under different types of land use, soil texture exhibited resembles composition of particle size, and the composition of particle size changed little with depth (supplement figure 3). In consistent with the result in different counties, soil in this watershed consisted mainly of coarse silt and followed by fine sand (supplement table 2).

P657, L19: How many of these 30 sites were located in watersheds 1, 2 and 3?

Reply: We have replenished this information in the manuscript as follow: "Five, six and four of these 30 sites were located in W1, W2, and W3 respectively. Four sites in each watershed were picked out based on terrain similarity and age distribution for the analysis of after-planting SMC variation in different watersheds."

P658, L10-11: These degrees refer to aspect, not temperature, so please remove all the "C" after the figures. Also, do the figures stand for angles in degrees, measured clockwise from north, so that 0-360_ is North and 180_ is South? If so, please rephrase and clarify in the text.

Reply: We have removed the "C" after the figures. Also we have rephrased and clarified the expression of aspect.

P658, L14: What is the difference between stand density and canopy density? Please explain it.

Reply: We have explained them in the manuscript as follow: Stand density: the number of trees every 100 m2. Canopy density: the percentage of an areal unit covered by tree canopy.

P660, L5-7: This contention is somewhat contradictory with the underlying assumption that soil texture is relatively homogeneous across the entire Loess Plateau region. If this assumption is not correct, please provide soil texture data for the 3 different watersheds at least.

Reply: The stable SMC of W3(8), W3(30), and W3(45) from the top down support our assumption that soil texture is relatively homogeneous across the entire Loess Plateau region. Therefore the speculation in the primary manuscript that the high SMC in W3(10) was probably attributed to "soil texture and physicochemical property divergences" is somewhat arbitrary. We rephrased relevant content in 3.1, analyzed the raw data again, and gave some other support for SMC divergence in discussion 4.1.1 as follow: "In watershed W3 (Fig. 3c), the characteristic of soil profile implied an absence of water supply for a long time. In 8-, 30-, and 45-year old stand, SMC was near the wilting point (Li et al., 1996; Meng et al., 2008). Therefore, water was not consistently available to plants. In the 10-year-old stand, SMC was slightly higher than the wilting point and can be used by plants partially, and this deduction was proved by slightly decreasing trend from 20 to 60 cm. No obvious trend was found between SMC and stand age. The SMC variation probably came from differences in terrain and soil texture. In the Loess Plateau, soil texture is uniform, and SMC divergence in different stands probably came from terrain variation (slope, aspect and slope position). Four stands were all located in the up slope. No trend was found between SMC and slope and SMC in 10-year-old stand which had the steepest (26°) slope was highest. This result was inconsistent with most of previous studies. Though slope has an important effect on rainfall redistribution on slope, after long-term drought SMC exhibited no significant trend with slope. Comparatively, relationship between SMC and aspect were more comprehensible. The aspects of 8-, 10-, 30-, 45-year-old stands were 135°, 45°, 204°, and 90° respectively. According to the influence of aspect on solar radiation reception on slope surface, they were graded further to 3, 4, 1, 3 (grade 1 stands for slope aspect having the highest solar radiation reception while 4 the lowest). The corresponding depth-averaged SMC was 4.4%, 6.3%, 2.9% and 4.2%. Southwest-facing slope had the lowest SMC followed by east- and west- facing, and northeast-facing slope had the highest SMC. SMC increased with decreased solar radiation reception. Therefore SMC in W3 probably depended on slope aspect which exerts great effect on the solar radiation reception on slope."

P660: I recommend to eliminate the whole 3.2 Section, as the true relationships between environmental factors and soil moisture are greatly overshadowed and confounded by the rainfall gradient at the regional scale. I think the relevant scale to investigate these relationships is the watershed scale.

Reply: this section will be deleted in the revised manuscript.

P660-661 and Fig 5: Again, I think it would be much more adequate and informative to conduct separate CCA analyses for each watershed, and then compare the results between watersheds.

Reply: The process of CCA is extracting important dimensions from lots of factors based on numerous data. Large enough sample size is the prerequisite of CCA analysis. In watershed scale, CCA application is limited by sample size. Nevertheless we have improved the analysis in watershed scale by adding some other relevant information for further analysis.

P661, L11-12: This result supports my view that the relationships between SMC and environmental parameters will likely be very different between watersheds due to widely divergent climates.

Reply: Due to climate variation, the relationship between SMC and environmental parameters was indeed different between watersheds, and this has been also proved in some other places.

P662, L8-14: I think this is the correct way to analyse the data, so please conduct similar analyses to evaluate the influence of all the other environmental parameters.

Reply: We will evaluate the influence of the other environmental parameters in the revised manuscript.

P663, L1: evapotranspiration instead of evaporation. Reply: We have changed it.

P663, L4-5: Once again, how uniform is soil texture within and across watersheds in this region?

Reply: please refer to the reply above.

P663, L11-13: Is self thinning in high density stands an important process in these afforested plantations, and the major reason for decreased stand density with stand age? Please clarify.

Reply: In the afforested plantations, several reasons (eg. self thinning and severe environment) may lead to the decrease of stand density. This hasn't been elaborated in the manuscript, and we will discuss stand density variation further as follow. Density-dependent mortality leads to self-thinning in crowded population. In this case, populations decline in density as plant size increase, and the concomitant change can be described by a logarithmic equation: $\log w = \log k + a \log N$ w: plant size; k: constant; a: constant with an ideal value at -1.5, and has been generally thought to lie between -1.3 and -1.8. N: stand density.

In our study, we use DBH as an indicator of plant size. According to the result of nonlinear regression (Supplement figure 4), the a-value in W1 was on the verge of a-value for self thinning. In W1, constant and high canopy density meant space and resources competition between individual trees; meanwhile high stand density in young stand and the decreasing trend of stand density with stand age (Supplement figure 5) implied a density-dependent mortality. Therefore in this watershed self-thinning was probably an important process accompanying with afforestation. In W2 and W3, stand density and canopy density was low and drought led to high mortality of planted sapling. Drought instead of self-thinning became the main factor affecting the mortality rate. In W2, stand density and canopy density decreased with stand age this may be a reflection of soil moisture depletion and the aging of trees. Over forty years, the canopy density in W3 was only about 3% due to severe water shortage, though modest canopy

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density can be maintained at initial stage of the plantation (Supplement figure 5).

P663, L24-28: please rephrase the whole paragraph, as it is difficult to understand in its present form. The meaning of the terms “shielding” and “low suction force for water” is unclear in this context.

Reply: We have explained “shielding” and “low suction force for water” further. The shielding effect has been explained complementally “The shielding cover isolates the top soil with sunlight and upper air and may affect the energy exchange between the soil and atmosphere.” “low suction force for water” was replaced by “low suction force between soil particles and water”. Moreover we have rephrased the whole paragraph to make it clear. “The soil surface is important for energy and matter exchange in the soil-plant-atmosphere system. Herbaceous cover exerts an effect on SMC via root water uptake and the provision of a shielding cover. Loess soil shows strong evaporation potentials due to its uniform texture, developed capillary porosity, and low suction force between soil particles and water (Hu and Shao, 2002). The shielding cover isolates the top soil with sunlight and upper air and may affect the energy exchange between the soil and atmosphere. It probably decreases the diurnal temperature and temperature variation in the topsoil (Tesař et al., 2008; Verhoef et al., 2006). Lower topsoil temperature leads to decreased evaporation from bare soil and increased condensation (Alvarez et al., 2006). Therefore shielding cover will improve soil moisture conditions in the topsoil, and the effect diminishes with soil depth. Plant root water uptake for transpiration has a negative effect on SMC. In the uppermost soil, shielding cover effect on SMC surpasses plant root water uptake effect on SMC, and SMC is high under high herbaceous cover. With the increase of soil depth, shielding cover effect on SMC may be counteracted by plant root water uptake. In this study, SMC was positively correlated to herbaceous cover significantly in the top 10 cm soil profile ($r=0.366$, $P<0.05$, Table 2), and in soil profile below 10cm no significant relationship was found.” P664, L24-25: What do you mean by “shadowed roots”? Please reword and clarify.

Reply: We have changed “shadowed roots” to “shallow roots”.

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Table 2: The correlation between Stand age and SMC at 30-40cm depth must be wrong, please correct this error.

Reply: We have corrected this error.

Fig 2. Please provide the N (sample size) for each soil moisture profile.

Reply: We have provided the N.

Fig 4. Please conduct separate analyses for each watershed.

Reply: In each watershed, this kind of analysis is limited by data volume, but we analyzed more environmental factors to strengthen our analyses in watershed scale.

Fig 5. Please consider conducting separate CCA analyses for each watershed.

Reply: Please refer to the reply for "P660-661 and Fig 5".

Fig 6. I think the relationship in fig 6b (watershed 2) is asymptotic (reflects a saturation response of SMC when SOM content is greater than about 12 mg per gram of soil).

Reply: We analyzed the data further as follow. "In W2, SMC and SOM didn't show out significant relationship (Fig. 6b). When the point with the highest SOM was removed (this point may reflecting a saturation response of SMC when SOM content was greater than about 25 mg per gram of soil), SMC and SOM was correlated significantly ($r=0.735$, $P=0.01$), however this relationship derived from variations of these two factors with soil depth (for SMC $r=-0.775$, $P<0.01$; for SOM $r=-0.914$, $P<0.01$). When depth was assigned as control factor, the partial correlation coefficient between SMC and SOM was 0.102 ($P=0.779$). On the contrary, partial correlation coefficient between SMC and SOM in W1 was 0.786 ($P<0.0.01$). This reflected the real effect of SOM on SMC in W1. In W2 and W3 (Fig. 6b, c), the irrelevant relationship between SMC and SOM indicated a diminished effect of soil water-holding capacity on SMC."

Reference

Zhang, X. Z.: Study on the composition of soil particles and texture zoning of the Loess Plateau, Soil and Water Conservation in China, 3, 11-13, 2002. Xiong, Y., Li, Q. K.: Soil of China, Beijing: Science press, 1987.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 653, 2011.

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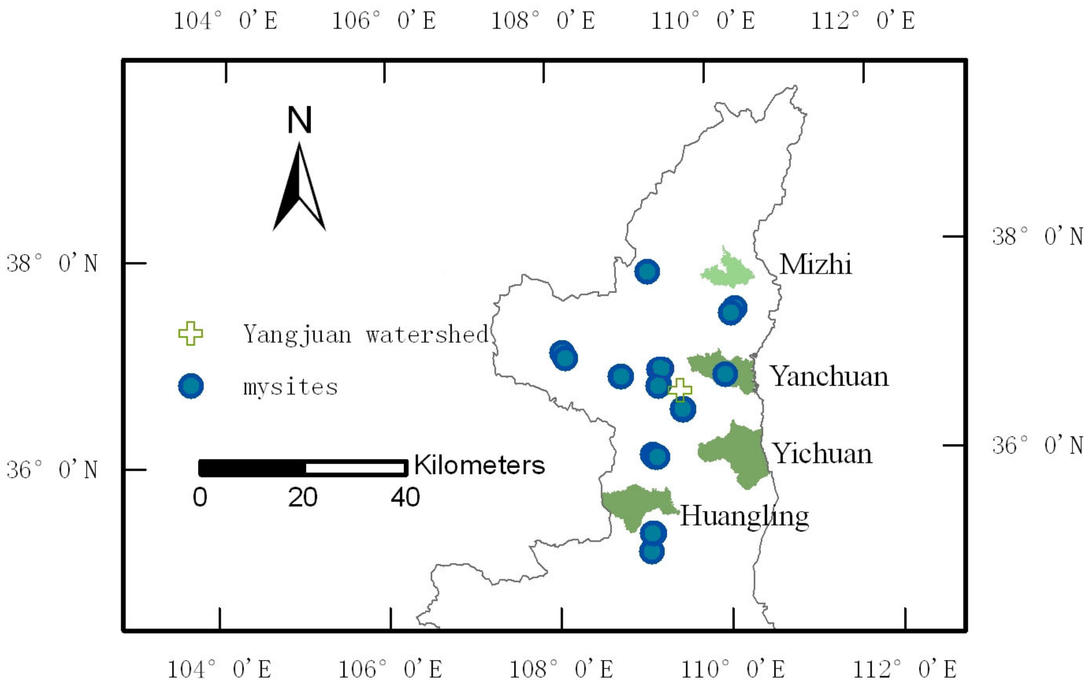

Fig. 1. Supplement figure 1 Location of four countries and Yangjuan watershed

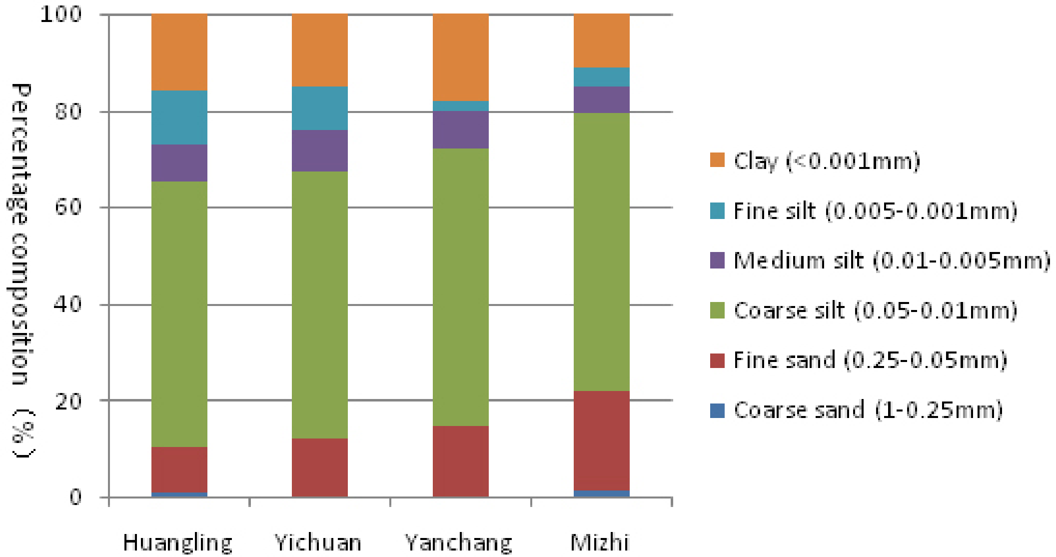

Fig. 2. Supplement figure 2 the composition of soil particle size in the northern Shaanxi Province (Zhang, 2002)

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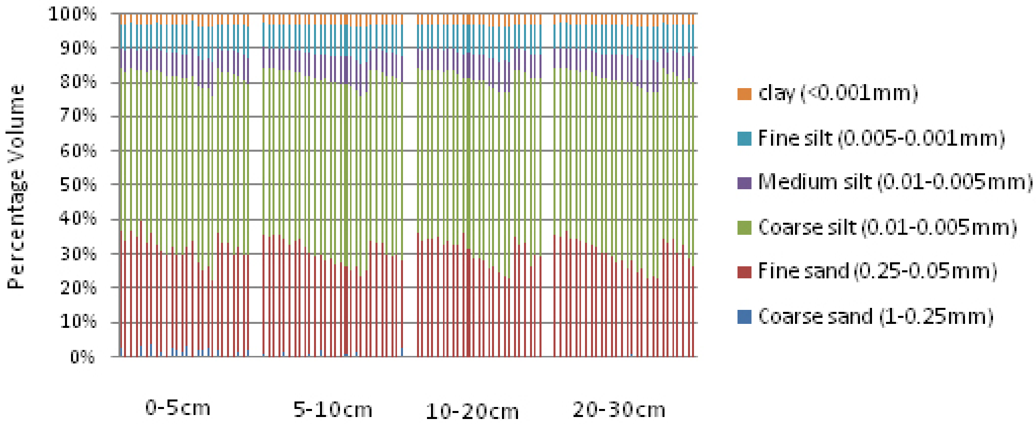

Fig. 3. Supplement figure 3 soil particle size distribution in Yangjuan watershed located in the northern Shaanxi Province (Unpublished data)

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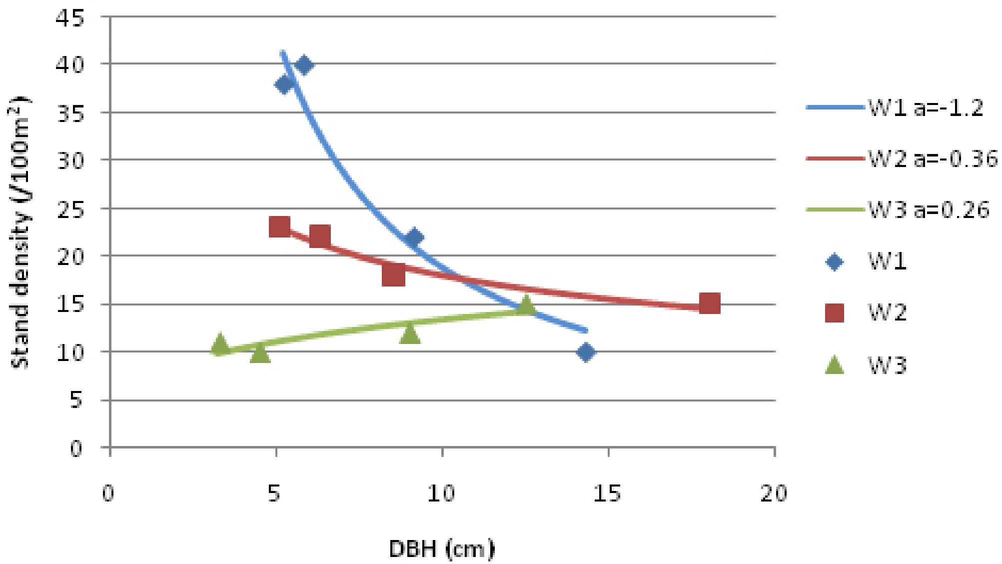

Fig. 4. Supplement figure 4 logarithmic regression between plant size and density

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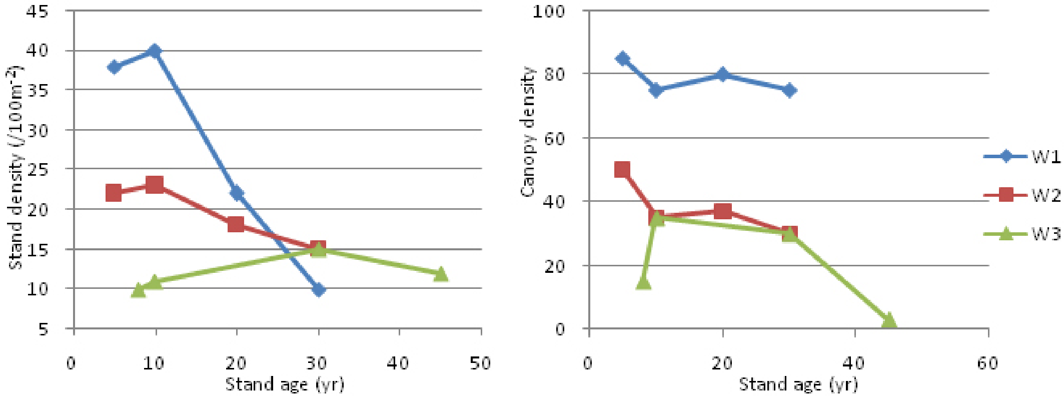

Fig. 5. Supplement figure 5 stand density variation with stand age in different watersheds

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The soil texture classification standards				
Texture classifications		Composition of particle size (%)		
Group	Class	Sand (1-0.05mm)	Coarse silt (0.05-0.01mm)	Fine clay (<0.001)
Sand	Coarse sand	>70	-	<30
	Silty sand	>60~<70	-	
	Dust sand	>50~<60	-	
Loam	Sandy silt	>20	>40	
	Silt	<20		
	Sandy loam	>20	<40	
	Loam	<20		
	Sandy clay	>50	-	>30
Clay	Silty clay	-		>30~<35
	Loam clay	-		>35~<40
	Clay	-		>40~<60
	Heavy clay	-		>60

Xiong and Li (1987)

Fig. 6. Supplement table 1 the soil texture classification standards in China (1987)

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Upslope	Soil depth	Coarse sand (1-0.25mm)	Fine sand (%) (0.25-0.05mm)	Coarse silt (%) (0.01-0.005mm)	Medium silt (%) (0.01-0.005mm)	Fine silt (%) (0.005-0.001mm)	Clay (%) (<0.001mm)
95% Confidential intervals	0-5cm	0-4.41	23.17-38.83	46.31-54.47	5.24-8.88	6.43-9.95	2.22-3.56
	5-10cm	0-2.08	22.91-37.66	47.81-54.25	5.33-8.92	6.28-10.15	2.42-3.46
	10-20cm	0	22.77-38.78	46.34-55.06	5.24-8.93	6.30-10.09	2.39-3.48
	20-30cm	0-0.46	22.02-38.71	46.46-55.19	5.33-8.96	6.39-10.06	2.38-3.50

Fig. 7. Supplement table 2 soil particle size distribution at different depth in Yangjuan watershed (Unpublished data)

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