The Spatial Variation and Impact Factors of Soil Saturated Hydraulic Conductivity in ShaleHills(CZO)

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Background

Horizontal and vertical heterogeneity of soil types and their properties make predicting flow in soils and hillslopes difficult. A better understanding of the spatial variability of soil hydraulic properties and underlying processes responsible for this variability could lead to a more accurate modeling in catchment hydrology, ecology, and contamination mitigation. The field soil saturated hydraulic conductivity (K_s) exerts a dominating influence on the soil water storage, erosion processes and the partitioning of rainfall in vertical and lateral flow paths.

ShaleHills that we have been studying is steeply sloping and forested. This implies that soil-landscape relationships need to be considered simultaneously so as to understand adequately the complexity in the catchment hydrology.

Two main objectives for present study are (1) to determine the field soil hydraulic conductivity for a shale area; 2) to figure out the spatial variability of soil hydraulic conductivity in relation to soil and landscape features (e.g. location, slope) in ShaleHills.

Field Experiments

Filed infiltrations were conducted in the Susquehanna ShaleHills Critical Zone Observatory, which is a 7.9-ha, forested catchment located in central Pennsylvania, US. This V-shaped catchment is characterized by steep slopes (up to 25-48%) of concave, convex and linear geometry with narrow ridges. The valley is oriented in an east-west direction separating steep almost true north-facing and south-facing slopes. The relatively uniform side slopes are periodically interrupted by seven distinct swales of varying sizes on both sides of the stream. There are four basic landforms in this catchment: 1) north-facing hillslope with deciduous forest and little underbrush, 2) south-facing hillslope with deciduous forest and thicker underbrush, 3) valley floor or floodplain of a first-order headwater stream, 4) topographic depressions (swales) containing deciduous forest and deeper soils.

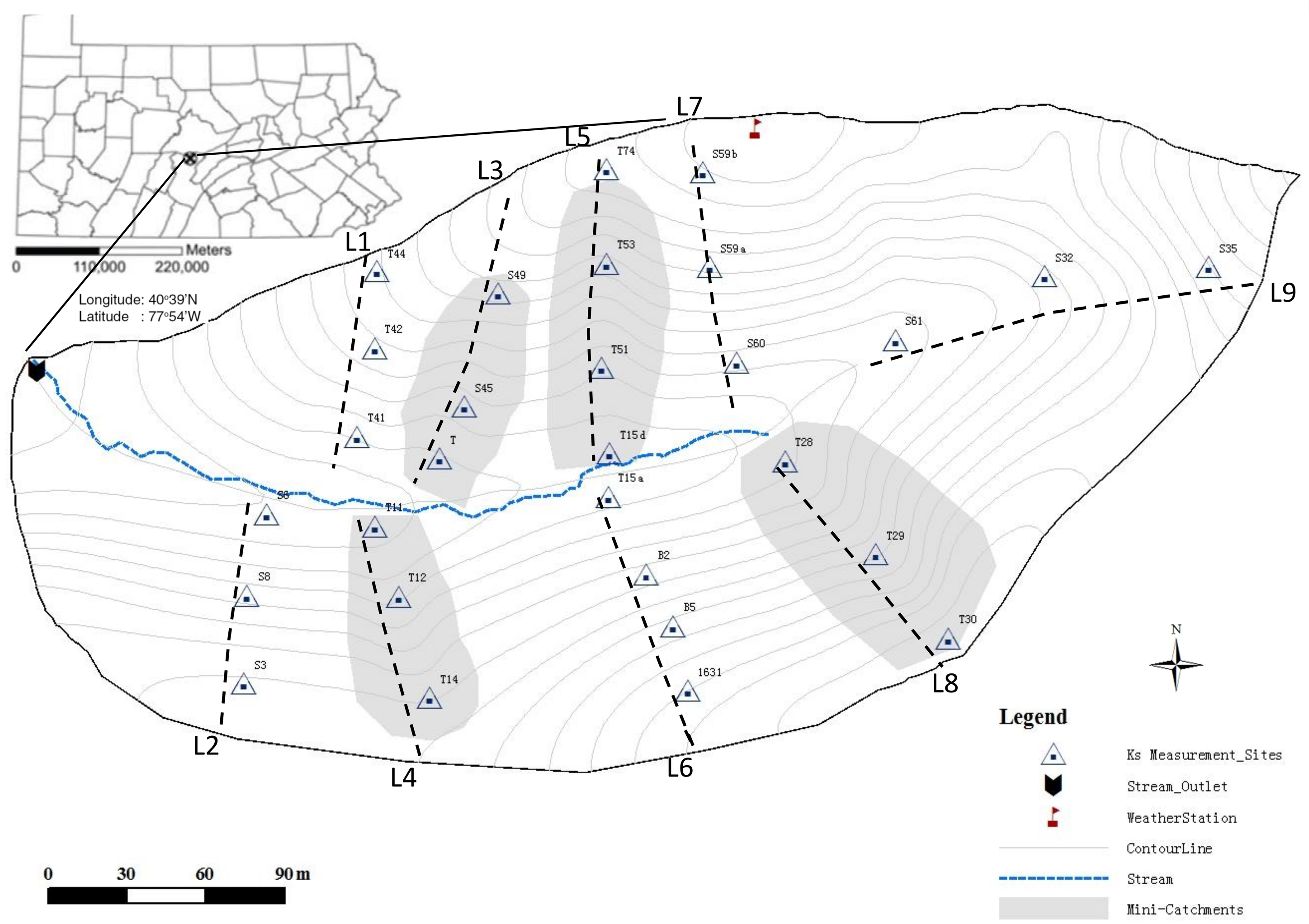

Fig.1 The distribution map of all the 29 experimental sites in ShaleHills

Totally 29 sites, covering various hillslope positions and soil types, were selected across overall the ShaleHills catchment to conduct the field infiltration experiments. The 29 sites distributed at the **top-slope**, **mid-slope** and **valley** along both the **north-** and **south-facing slopes**. In addition, both the **planar** and **swale slope** were involved in this study to investigate the impact of slope type on K_s.

Considering the fact of steep hillslope in this research, the Turf-Tec infiltrometer was applied with a inner-ring=64mm, outer-ring=114mm. In order to obtain a reliable and representative measurement of soil K_s, **three replicate** sets of infiltration were taken at each experiment site. The three sub-locations were arranged in the three corners of a triangle area with about 40cm apart from each other.

The time interval for re-adding water was varied from site to site due to the difference of infiltration capability. The test progressed until the rate of infiltration was considered constant or steady state was reached. The full tests were conducted for a period of two hours in most cases. A minimum of 90 min was taken to obtain a reliable measurement even the infiltration reached a steady state very soon.

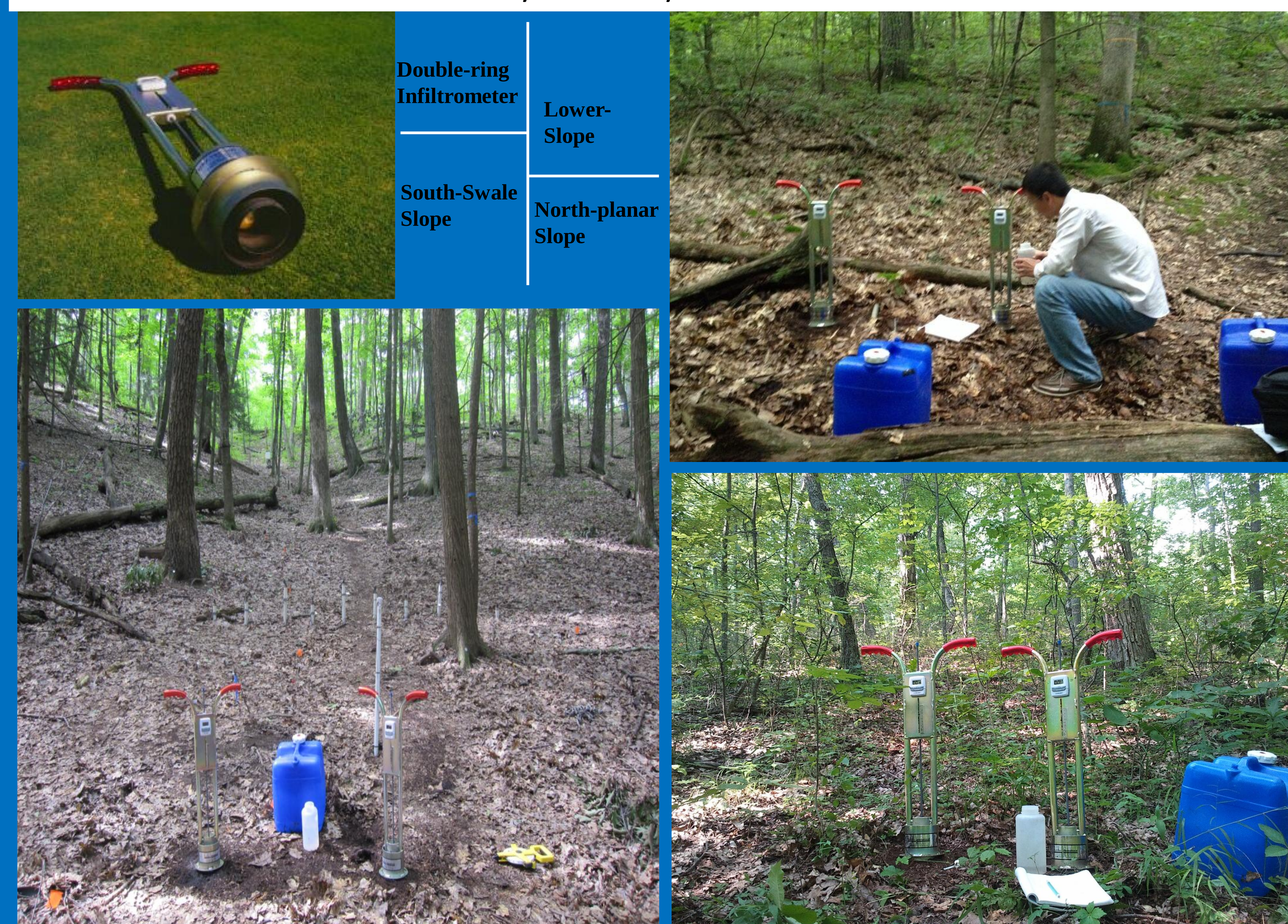

Fig.2 The experimental sets in the field

Results and Discussion

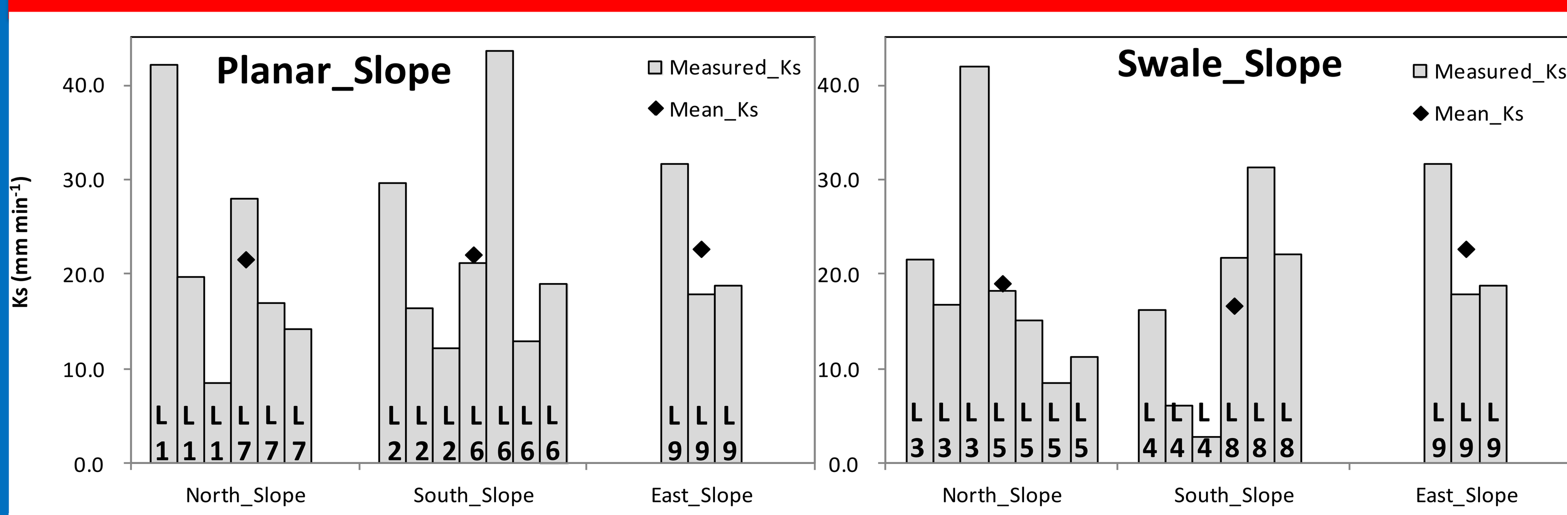

Fig.3 The variation and comparison of the Ks between different facing of the slope

- Two groups of K_s (i.e. planar-, and swale-slope) were set and analyzed separately in order to eliminate the effect of slope type on K_s.
- As shown in Fig.3, due to the high variation of K_s along the slope lines, it was hard to tell the difference of K_s between the north- and south-slope, and both the planar- and swale-slopes showed similar features.
- If the mean values of K_s were considered, no significant difference of K_s was observed between the north- and south-slope.

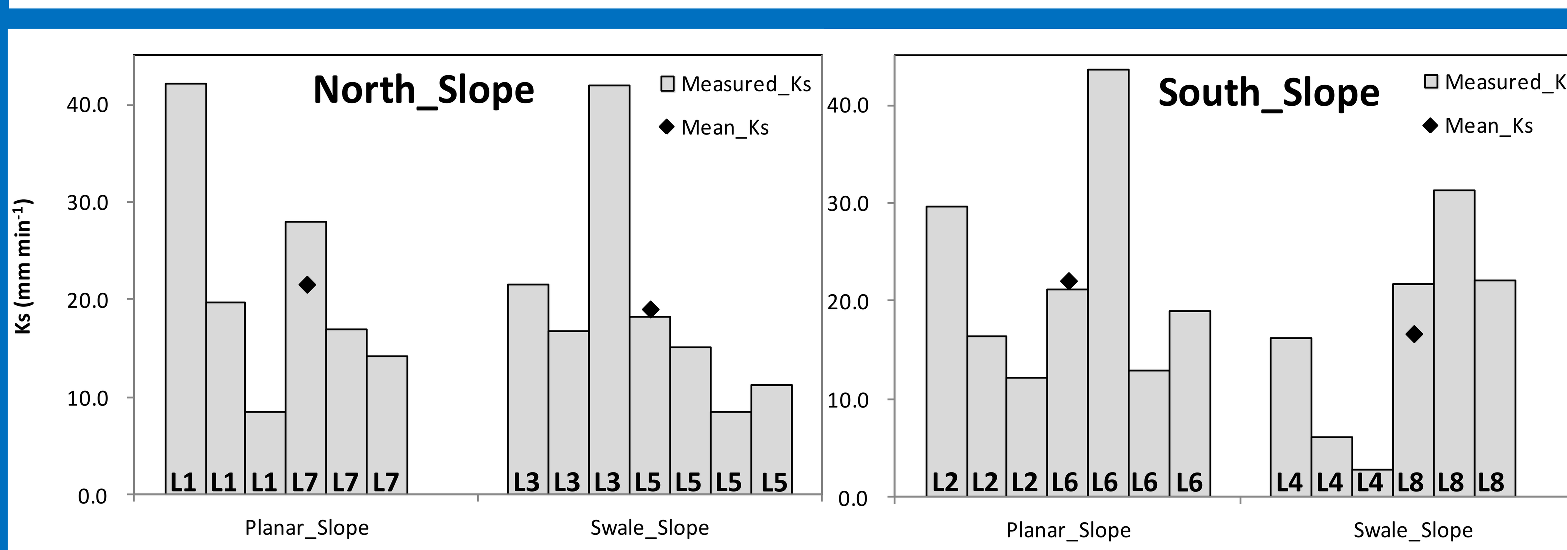

Fig.4 The variation and compare of the Ks between different types of slope

- In general, the K_s values on the planar-slope were comparable with those on swale slopes, although it was shown high variation in K_s for any one type of the slopes.
- However, as it was indicated by mean values of K_s, the K_s' on planar-slopes were a little higher than those on swale-slopes for both the north- and south-slope.

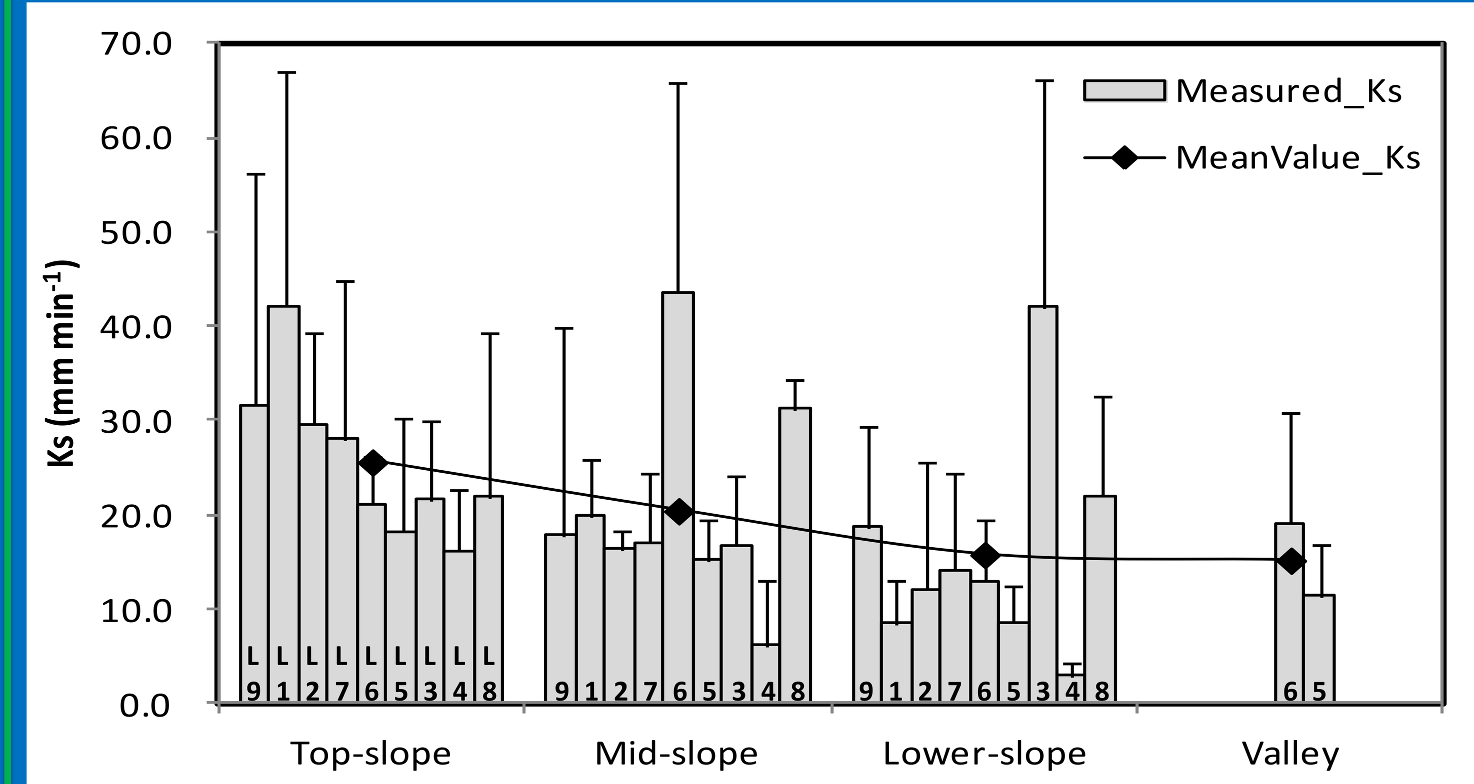

Fig.5 The variation and distribution of the K_s at different location of the slope

- The **variation of K_s was strong** among the nine slope lines although they were in similar location of the slope
- The K_s was **higher at the top-slope** than that at the mid-slope, and the lower-slope has the lowest K_s.
- The mean value of K_s over nine slope lines also showed that the K_s was greatest at the top-slope and then decreased downward along the slope.

Table 1 Independent samples test for the measured Ks of different groups

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
North-South (Planar)	0.037	0.851	-0.078	0.939	-0.498	6.402	-14.589	13.594
North-South (Swale)	0.077	0.787	0.392	0.702	2.367	6.033	-10.911	15.646
Planar-Swale (North)	0.179	0.680	0.399	0.698	2.536	6.362	-11.467	16.539
Planar-Swale (South)	0.000	0.990	0.889	0.393	5.401	6.076	-7.971	18.774
Top-Mid	0.149	0.705	1.148	0.268	5.169	4.502	-4.374	14.713
Top-Lower	0.225	0.642	2.123	0.050	9.839	4.634	0.016	19.662
Mid-Lower	0.007	0.933	0.896	0.383	4.669	5.210	-6.375	15.714

- The *t*-test with "equal variances assumed" was used.
- The difference of K_s measurements between **top-slope** and **lower-slope** were **significant** (the 2-tailed significance was 0.05).
- K_s measurements between any other two groups of slope were no statistically significant difference.

- The distribution of Ks also showed high variation in the catchment scale.
- There was an order of magnitude difference between the highest and lowest values of Ks.
- In general, the Ks in the area of upper stream was higher, and then decreased down-wards the stream.

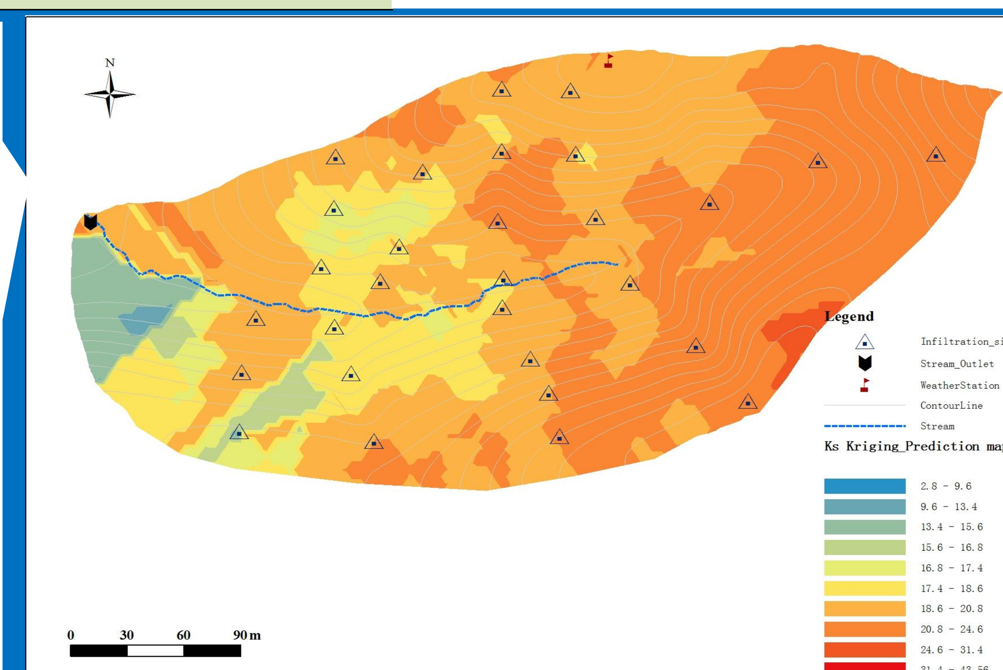

Fig.6 The distribution of Ks in the ShaleHills catchment.

Conclusions

- The variation of K_s in ShaleHills was high at both the local scale and catchment scale.
- The location on the slope was the only factor which showed significant influence on the distribution of K_s.
- The effect of slope type on the distribution of K_s was appreciable. However, the impact of slope aspect on K_s distribution was not observed in present study.
- Landscape position was a very important factor and should be taken into account in K_s measurement on a forested catchment with steep slope like ShaleHills.

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Lin, H. (2006). Temporal stability of soil moisture spatial pattern and subsurface preferential flow pathways in the Shale Hills Catchment. *Vadose Zone Journal*,*5*(1), 317-340.

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