



Spatial distribution characteristics of phosphorus and potassium in small watershed of grassland

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ABSTRACT

Phosphorus (P) plays an important role in plant nutrition. Many important organic compounds in plants contain phosphorus, which can promote crop growth and enhance the cold and drought resistance of crops. Potassium (K) can promote photosynthesis, increase plant uptake and utilization of nitrogen. In small grasslands, the growth status of vegetation is closely related to phosphorus and potassium; therefore, it is important to understand the spatial distribution of P and K in watersheds. In this report, a small closed watershed of Xilamu grassland was selected as the study site. The total phosphorus and potassium contents of soil samples were detected by laser induced percussion technique and the contour map of phosphorus and potassium elements in the watershed were plotted by CAD and other mapping software. By analyzing the distribution of contour maps, the spatial distribution characteristics of phosphorus and potassium in the watershed were determined. The distribution of phosphorus and potassium elements in the watershed has some similarities. Both elements are abundantly rich in the study area. The content of phosphorus and potassium in the runoff area of the watershed was also relatively high.

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INTRODUCTION

Scientists who studied spatial distribution of phosphorus and potassium content focused their researches on different geomorphological sites and analyzed the changes on the top of slopes, the slopes and the bottom of slopes. Their methods of determining the content of the elements were all traditional experimental methods. Yang (2015) studied the stoichiometric characteristics of soil carbon, nitrogen and phosphorus in different landforms of secondary forest land in Karst area. His results showed that the soil organic matter and total nitrogen content were higher at the foot of the mountain, and that there is great difference between the hillsides and the top of the

mountain. Total phosphorus content in the top of the mountain is higher than the foot and hillsides. Wang (2006) studied the chemical properties of different landform types. His results showed that potassium ions were enriched in the valley area and drifted in loess hills and slopes, and Boron element in the soil showed that the hilltop has higher content, followed by hillside slope, and the lowest is in the valley terrace. In the vertical direction of different landform parts, the effective content of soil elements is highest in the valley terrace, loess hilly centered at the top and the slope is minimal. Changes in total phosphorus and total potassium content in different slope as well as slope characteristics have been of concern to scientists. The study of soil phosphorus and potassium content mainly focus on the influence of terrain conditions on the two factors and the distribution

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characteristics of them in different landform parts. The results show that slope direction influence the degree of phosphorus and potassium in Terrain factors. The spatial distribution of total phosphorus and potassium in different landform parts is highest at the slope foot, the lowest is at the top of hill. Slope foot and slope top reached significant different levels. But the available phosphorus and potassium did not have uniform distribution, and its spatial distribution was more complex than total phosphorus and total potassium (Liu et al., 2010; Niu et al., 2005).

Guo et al. (2003) used small watershed as a unit, analyzing the distribution characteristics of soil nutrient and its relationship with topography in different parts of slopes (on the top, on the slope and on foot) in the Zhongliuchuan small watershed of semi-arid region in Loess Plateau. Their results showed that the soil nutrient content and the available nitrogen were scarce, and the contents of soil organic carbon, nitrogen and phosphorus decreased from the top of the slope to the foot. The distribution of elements in the small watershed is closely related to erosion, due to the influence of wind erosion and water erosion on the slope. Wang et al. (2006) studied the characteristics of soil nitrogen, phosphorus and potassium migration with surface runoff at different slope conditions using the indoor rainfall simulation test. They pointed out that with increase in sloppiness, soil erosion increased, the runoff solute concentration increased, which resulted in reduced soil surface nutrient content. Reducing soil erosion is an important way to reduce runoff nutrient loss. Liu et al. (1995) studied nutrient loss of sloping land in the southern Loess Plateau, and pointed out that total nutrient loss increased with the increase of slope. Liu et al. (2003) preliminarily analyzed penetration law of the nutrient on the yellow soil slope through the slope plot test. The study pointed out that penetration ability of the different nutrients is different from the top of the slope to the foot, it is easy to enrich a certain layer, which has fast infiltration and large concentration of nitrate. In general, the higher the content of soil powdery particles, the greater the rainfall intensity; the greater the runoff, the greater the amount of sediment volume produced by soil erosion (Zhang et al., 2001; Shi et al., 2000). Compared with the initial nutrient content of the affected soil, the lost sediment has much nutrients (nitrogen, phosphorus and so on) than the soil. The nutrient content of the lost sediment is generally high, and the regularity changes with the increase in the volume of rainfall (Xue et al., 2004). Guo and Song (2014) showed that under simulated rainfall, the sediment of three different types of sloped soil had nutrient enrichment. The nitrogen and phosphorus enrichment coefficients of the lost cinnamon soil and red soil slope (14.27~73.55% and 6.56~52.07%), potassium enrichment coefficient of the lost brown soil slope sediment was

higher than the cinnamon soil and red soil slope 55.83~67.28%.

LIBS technology is a Laser induced breakdown spectroscopy. Due to the unique characteristics of LIBS technology, it is widely used in all walks of life (Zhang et al., 2015). Fortes et al. (2008) used LIBS as a diagnostic tool to analyze and evaluate archaeological samples; Arca et al. (1996) studied the application of LIBS in wastewater testing. Agondal et al. (2009) used laser induced breakdown spectroscopy for the monitoring and remediating of Cr metal in contaminated soil. Kerem et al. (2009) used this technique to study the characteristics of oil painting materials in a Turkish church and put forward how to carry out conservation and protection methods. Xu et al. (2013) used LIBS to rapidly test the Na content in milk. Zhang et al. (2013) analyzed plasma emission spectroscopy to rapidly detect the information of Cr elements in medicinal capsules, using LIBS technique rapid detection of Cr content in medicinal capsules can be done in 10 sec. It can be seen that LIBS in practical application are very good.

In this paper, the content of phosphorus and potassium was measured by laser induced breakdown technology in Xilamuren small watershed. LIBS technique was used to detect the sample content with very small damage to the sample, and the sample was not pretreated thereby eliminating the cumbersome sample digestion process. This also enable us to avoid secondary pollution of the sample, and the detection cost is low. Also, it is suitable for large quantities; a timely analysis of sample elements, and can save a lot of time and cost. The content of phosphorus and potassium obtained can be mapped out using CAD and other mapping software drawn on a contour map. The results of the study provide scientific guidance for grassland restoration and soil and water conservation, and also increase the protection of vegetation in future water and soil erosion control.

MATERIALS AND METHODS

Study area

The river is located in the transitional zone of the Yinshan Mountains to the central part of the Inner Mongolia Plateau. The geographical position located is at 111° 12' 27.69" E - 111° 13' 40.32" E, 41° 21' 9.25" N - 41° 21' 40.62" N with an average elevation of 1600 m, which belongs to the semi-arid continental monsoon climate (Figure 1). The average annual temperature is 3.4°C, the months which average temperature is $\geq 10^{\circ}\text{C}$ mainly concentrated in the 7th, 8th and 9th months, and annual accumulated temperature is 2298.9°C. The average sunshine hours is 3172 h, frost-free period is about 106 days, and the average annual solar radiation is 142.45 Kcal/cm². The average annual precipitation is about 250

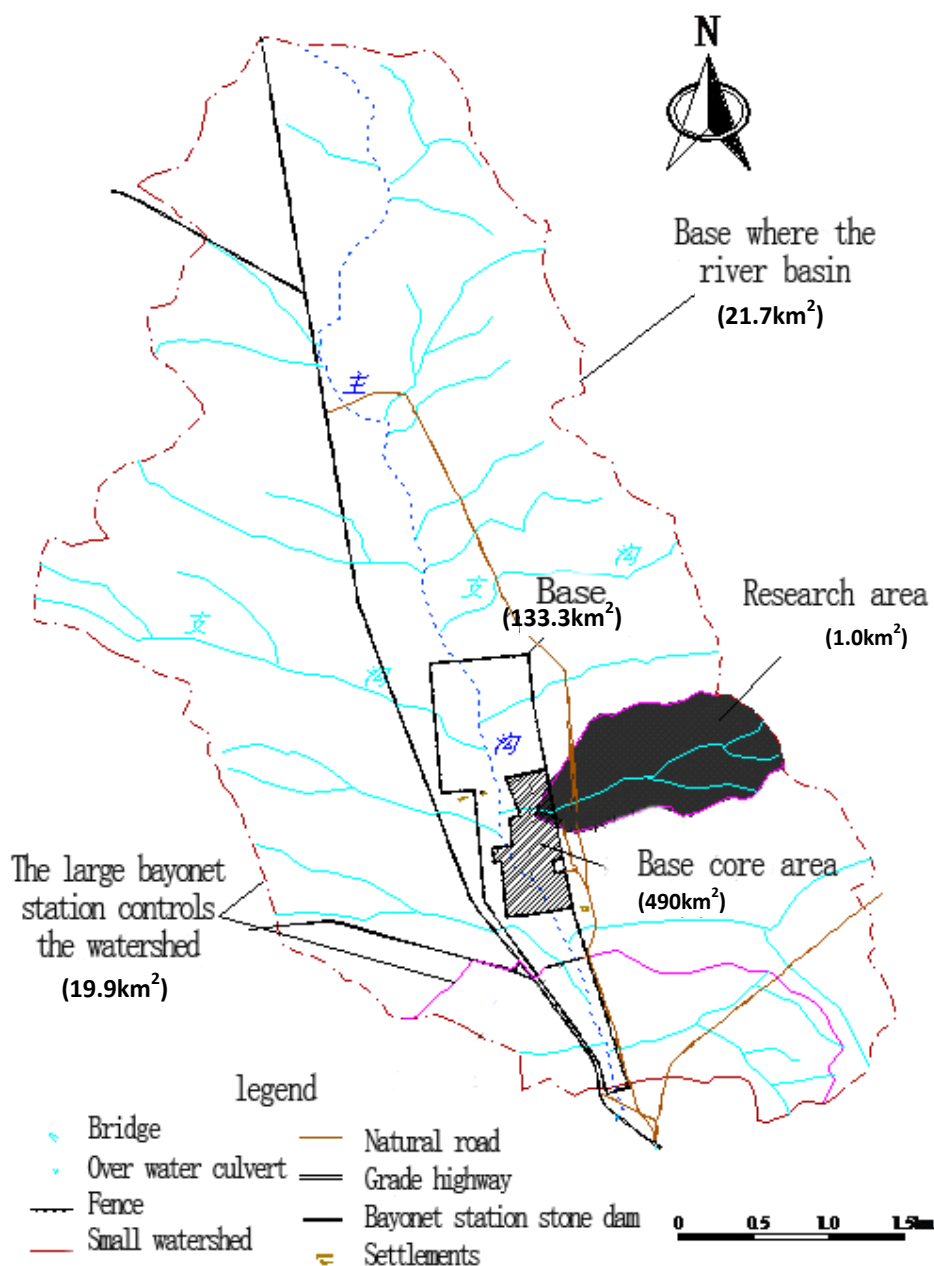


Figure 1. Overview of the study area.

mm, mainly concentrated in 7th, 8th and 9th months. The average annual evaporation capacity is 2227.3 mm, 7.9 times more than the amount of the precipitation. The annual average wind speed is 3.2 m/s, and the main wind direction is north wind and northwest wind. The number of windy days when wind speed ≥ 17 m/s is 68 days and the dust storm days is 20–25 days. According to the word reference basis (WRB) for soil resources, the study area is mainly distributed with KASTANOZEMS. Soil texture is mostly sandy soil, light soil, and have different degrees of

gravel. Soil fertility is generally low, organic matter content 1.0–1.8%. The dominant plants are *Stipa krylovii*, *Aritimisia frigida*, *Cleistogenes squarrosa*, *Agropyron cristatum*, *Leymus chinensis* and so on.

Field sampling

A closed small watershed was selected from the basin area of about 1 hm^2 in Xilamuren grassland area. Two

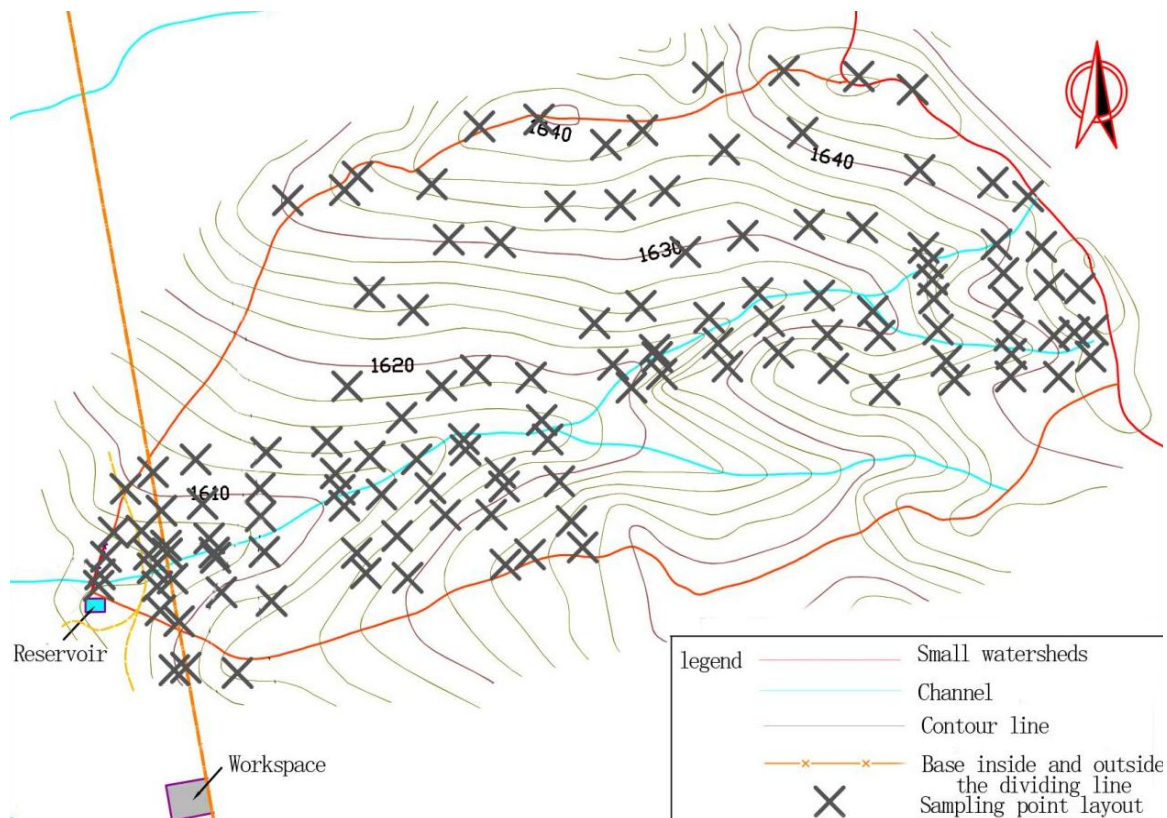


Figure 2. Layout of the sampling area in the study area.

percent of the watershed area is located in the fence of Ministry of Water Resources, Pastoral Water Conservancy Science Research Institute, for the ban, repair area, and 98% of the area is outside the test base fence. The selected altitude is 1610–1648.31 m. Sampling along the north and south sections of the small watershed, according to the length of each section and soil conditions was done to determine the number and location of sampling. These positions were specified by GPS in each sample (Figure 2). In the determined location, shoveling of surface soil with a small shovel, was done to obtain samples of about 500 g and were stored in kraft paper bag which was pre-labeled with numbers. A total of 130 soil samples were collected from the small watershed. The samples were taken to the laboratory where they were naturally dried. Grass roots impurities were removed before carry out the next experiment.

Determination of phosphorus and potassium content

Phosphorus and potassium content of the samples were determined using J200 element analyzer, which is a laser induced breakdown spectroscopy. It can detect samples

in various states (solid, liquid, gaseous), with minimum laser concentration, minimal damage to the sample is achieved, and there is no need for complex pretreatment of the sample. Also, it enables the elimination of tedious sample digestion procedure without causing secondary pollution of the sample. Specific operations include the following steps.

Gravel content were removed from the samples by an 18 mesh sieve (2 mm) before adding them to an agate ball mill. The quantity of the sample was not more than 2/3 of the tank, and each agate ball mill was then fixed on the turntable. The ball mill speed was set to the maximum for a period of two hours to allow the samples grind properly.

One gram of ground soil sample was weighed out added to 0.1 g Boric acid (H_3BO_4) as a binder. The combination was then mixed and moulded into tablets by an FYD-20 press plate to a diameter of 13 mm and a thickness of 6 mm. The tablet conditions were maintained at 16 MPa for 3 min.

This process involved two aspects. Firstly, an Axiom control software which obtains the spectra of the each sample's phosphorus and potassium elements. Secondly, a used data analysis software analyzes the Axiom spectral to determine the phosphorus and potassium

content in ppm.

RESULTS AND DISCUSSION

The predicted calculated concentrations of phosphorous and potassium are shown in Figures 3 and 4. Also, Figure 5 shows the topographic map of the study area. It can be seen that the terrain is northeast high and southwest low in study area from the figure. The flow direction inside the basin is related to the terrain, and the flow of water is from northwest to southwest.

Spatial distribution of phosphorus elements

As one of the vital elements of the biosphere, the high and low levels of phosphorus are not only affected by vegetation restoration and ecological environment, but also played an important role in the eutrophication of water in the area. Phosphorus in the soil is based on the nature of the compound. It is divided into organic phosphorus and inorganic phosphorus. Among them, insoluble inorganic phosphorus and organic phosphorus account for more than 95% of total soil phosphorus, which cannot be used directly for plants.

The contours of potassium content in the study area are shown in Figure 6, which is obtained by CAD. It can be seen from the figure that the phosphorus content in the eastern, central and western parts of the study area is changes obvious. The western part of the small water shed is relatively sparse, the phosphorus content is small, the highest value is 0.6988 g/kg, the lowest value is 0.6014 g/kg, and the change is 0.0974 g/kg. Here is the small watershed runoff gutter at the exit, phosphorus value appears the phenomenon of enrichment, phosphorus peak appears.

There are several obvious high values of phosphorus in the northern slope of the middle of the study area, and the contours are more intensive. The contours on the left side are sparse than the right side contours, and the changes in the right phosphorus content are significantly larger than those on the left side. The maximum value of phosphorus on the left side is 0.7398 g/kg, the minimum is 0.499 g/kg, the difference between the maximum and the minimum is 0.2408 g/kg, and the phosphorus content is not uniform. The right side of the contours to be relatively dense, phosphorus content distribution is very uneven, the maximum and minimum difference of 0.2527 g/kg, phosphorus content changes. The central part is the herd fence area, the high value area is just at the exit of the fence, the cattle and sheep are more intensive, the livestock excrement brings sufficient nutrients to the grassland, soil phosphorus content is relatively high. The low value of the top of the slope has a great correlation with the erosion.

In the eastern part of the study area, there was also a significant peak, the maximum phosphorus content reached 0.8446 g/kg, the minimum value was 0.5558 g/kg, the difference between the maximum value and the minimum value was 0.2888 g/kg, where the phosphorus content changed the most, The most uneven distribution, as the eastern source of the higher terrain, there is sufficient sunlight, and according to field investigation found that here formed depression, water and other nutrients gathered, vegetation grows well, formed the high phosphorus content area.

Spatial distribution of potassium

Potassium is an important nutrient element necessary for plant growth. It plays an important role in plant nutrition. Its content affects plant drought resistance, root growth and crop yield. There are many factors that affect soil potassium content, not only by parental factors. The contours of potassium content in the study area are shown in Figure 7, which is obtained by CAD. It can be seen from the figure that the distribution of phosphorus content in the study area is uneven, and there are obvious peaks in the eastern and central western regions. The contours are relatively close. The content of other regions of the contour is relatively sparse, little change in the content of potassium. There was a large peak and several small peaks in the western part of the study area. The minimum value of total potassium content was 23.0789 g/kg and the maximum value was 29.6284 g/kg. The difference between the maximum and minimum values was 6.5495 g/kg. It can be seen from the figure that the high-value areas are located in the vicinity of the fence, probably because the base was built in 2002, the fence around the vegetation repair period of more than ten years, strong vegetation growth, high potassium content, coupled with small waters western terrain Low and long-term surface runoff erosion and leaching, water flow in this region, the soil total potassium there is a significant "depression effect", potassium enrichment in this, resulting in a larger potassium content.

The maximum value of total potassium content is 34.1128 g/kg, the minimum is 26.0176 g/kg, and the difference between maximum and minimum is 8.0952 g/kg. For this large circle of equivalence, the contours of the southern end of the gully are more dense and the change is more obvious. The contours of the eastern part of the equal circle are also more intensive and the change is relatively obvious. The change of several other azimuths is almost the same Content changes evenly. At the same time, a sparse equal circle appears on the right side of the dense contour circle, and the change of potassium content in this region is more uniform. The middle of the two contours are internal potassium content

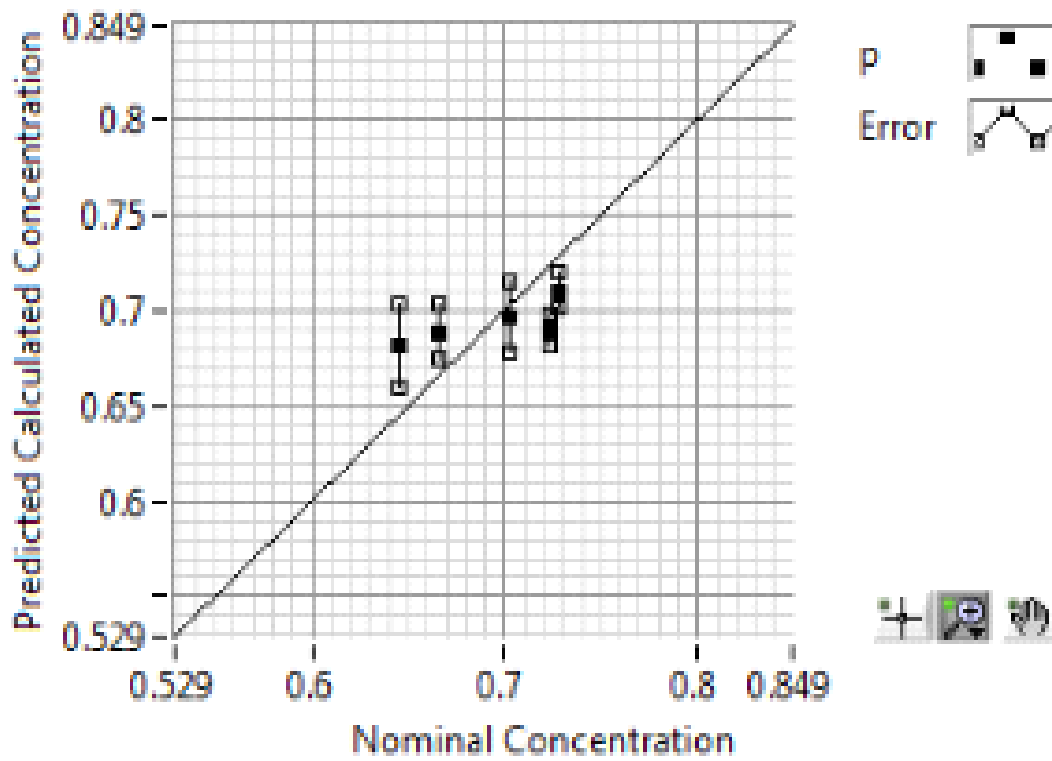


Figure 3. Standard curve of phosphorus element.

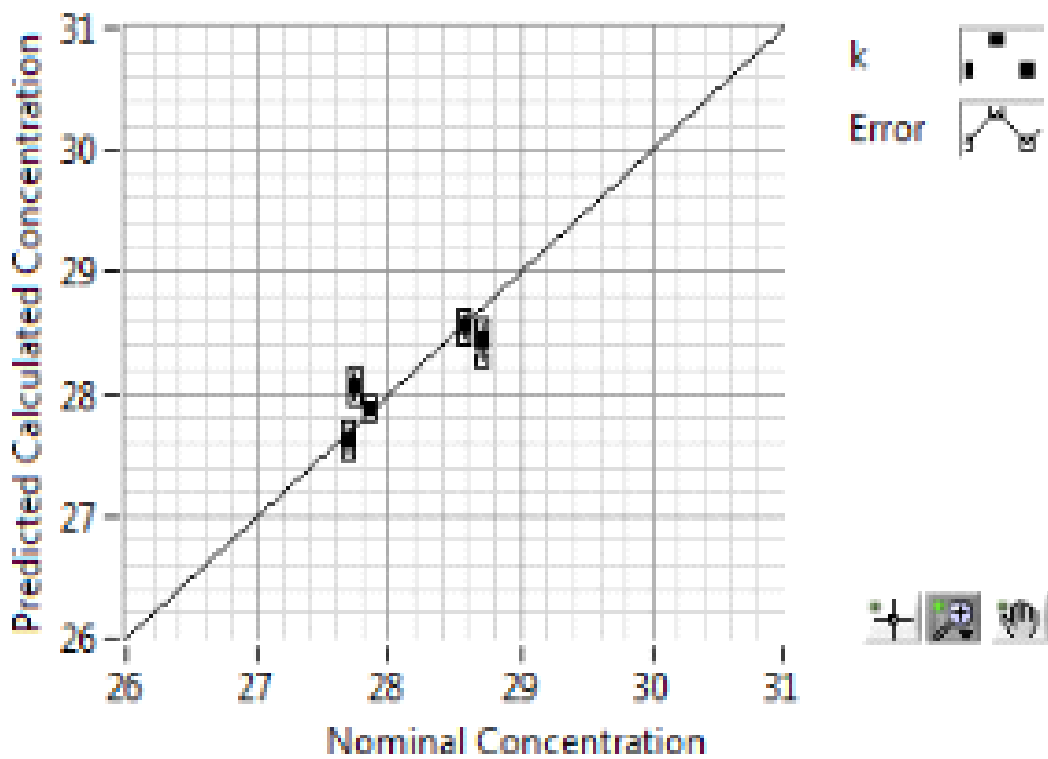


Figure 4. Standard curve of potassium.

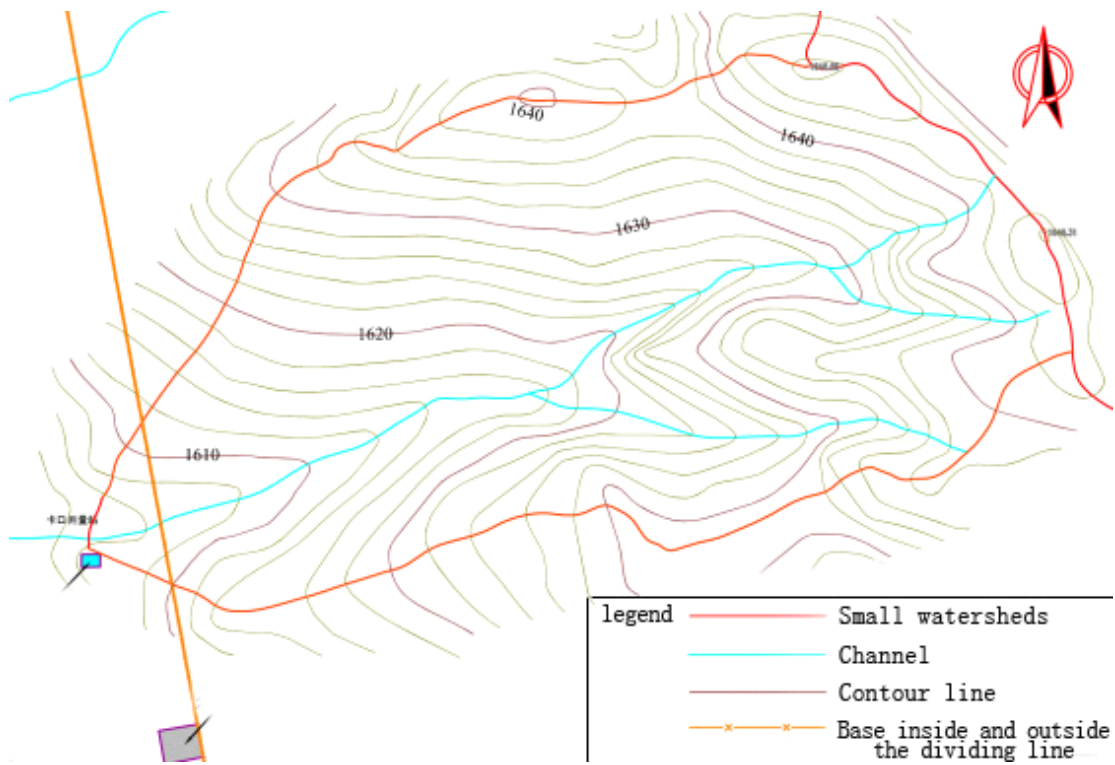


Figure 5. Topographic map of the study area.

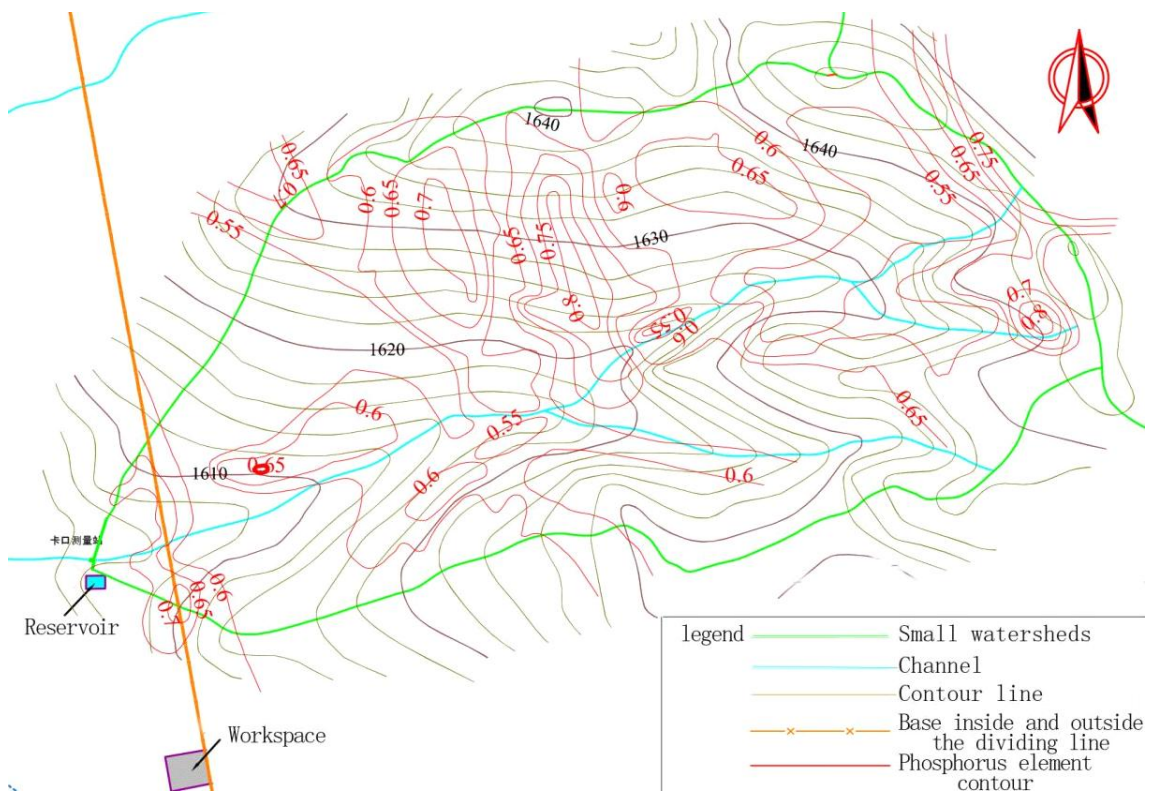


Figure 6. Phosphorus content contour map.

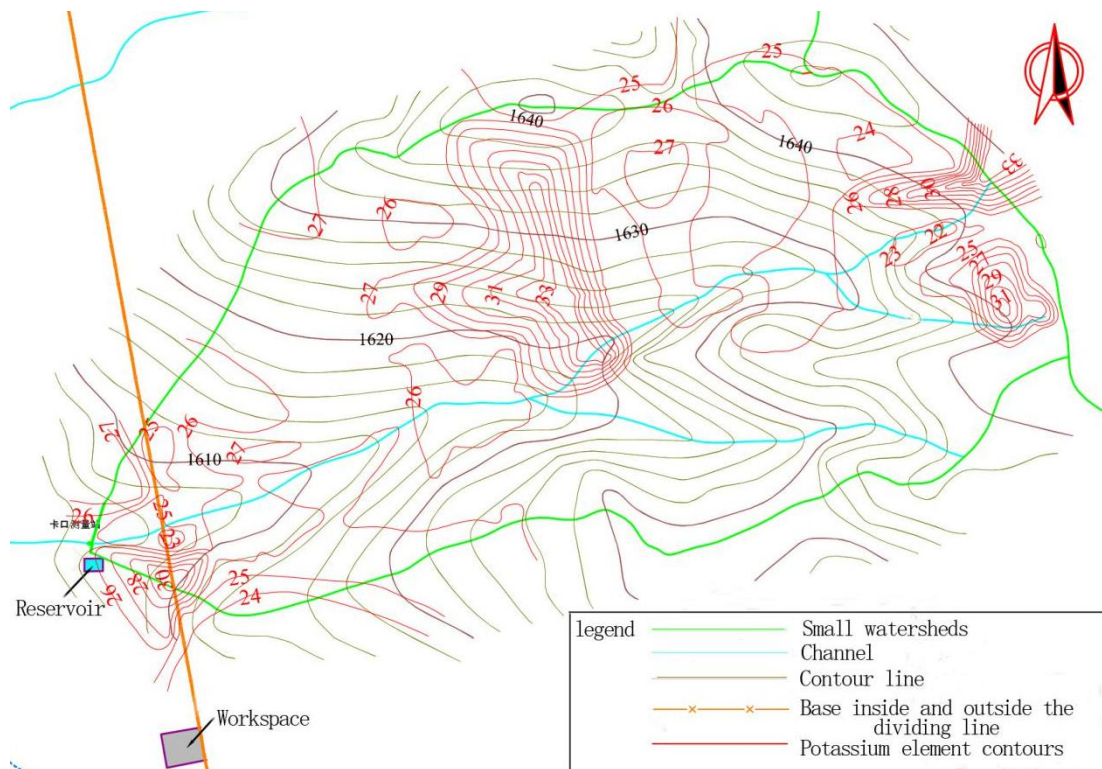


Figure 7. Potassium content contour map.

is high, the outermost content is low. The reason of high potassium and phosphorus content is the same, which is due to the nutrients excretion by livestock.

There are two contours in the eastern part of the study area. The area of the study area is smaller, but the contours are denser and the content of potassium is more obvious. The peak on the north side reaches 33.0014 g/kg, and the high potassium content is higher in the area where the altitude is higher and the total potassium content is lower in the lower altitude. The peak value is also internal, the highest value is 31.8504 g/kg, the lowest value is 23.5973 g/kg, the difference between the maximum and the minimum value is 8.2531 g/kg. According to the results of vegetation survey, the high content of potassium here is the growth well of vegetation in the east part of research region resulting from the high potassium content of parent material in well vegetation coverage, where there are a lot of exposed weathering rocks identified as potassium feldspar weathering by experts (Figure 7).

Conclusion

The distribution of phosphorus and potassium in the small watershed of grassland is analyzed by using LIBS

technology, which is fast, low cost and accurate. The conclusions are as follows.

The distribution of phosphorus in the small watershed is characterized by high content of phosphorus in the area with high vegetation coverage, high aboveground biomass and high vegetation height, as well as in the runoff "stranded" zone where the phosphorus content is high, and finally concentrated in the livestock where the phosphorus content is relatively high.

Vegetation growth in places where the relatively high phosphorus and potassium content, the basin surface runoff erosion will make phosphorus and potassium elements in the middle and bottom of the enrichment, breaking the top of the loss of phosphorus and potassium is relatively large, where the vegetation and soil fertility caused a great impact, in the soil erosion control, increase the protection of vegetation and stop the runoff rainwater is conducive to the prevention and control of soil fertility and soil nutrient loss.

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