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Linkage Analysis of Land Use/Cover Patterns and Hydro-Chemical Characteristics in Different Seasons in Ebinur Lake Watershed, China

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Abstract: Ebinur Lake Watershed, with its oases and deserts, is a typically arid and mountainous region on the northern slope of Tianshan Mountains. Along with ever increasing human activities, agricultural and domestic wastes have been directly discharged into river systems around the Watershed, which consequently poses a grave threat to the sustainable development of Xinjiang. Through statistical and spatial analysis, we have determined the relationships between land use/cover (LULC) and hydro-chemical characteristics during rainy and dry seasons in 2014. Spatial patterns of hydro-chemical characteristics as demonstrated by mineralization, pH, electrical conductivity (EC), and SO_4^{2-}, HCO_3^-, Cl^-, Mg^{2+}, Na^+, Ca^{2+} and K^+ concentrations were examined in 113 sites. Since hydro-chemical characteristics were affected by LULC patterns, this study delineated six zones to analyze the distribution characteristics of hydro-chemical parameters and its relationship with LULC patterns. The results showed that, except for the pH, all variables demonstrated significant spatial differences during dry and rainy seasons. In addition, the relationships between water quality and LULC patterns indicated that the farmland, forest–grassland, water body and salinized land all affected hydro-chemical characteristics during both rainy and dry seasons. Especially, decreased rainfall, irrigation, surface runoff, the area of lake, etc. largely led to the increase in ion content, which had great influence on hydro-chemical characteristics parameters in dry season. Furthermore, we established several stepwise linear multiple regressions models. The results showed that pH, mineralization and Ca^{2+} were defined by forest-grassland, while the Cl^- and Mg^{2+} were defined by salinized land during the rainy season. The pH and Na^+ were estimated based on farmland, whereas Cl^- and Ca^{2+} were estimated based on forest-grassland during the dry season. In conclusion, this research on the relationships between the spatial distribution of hydro-chemical characteristics in Ebinur Lake Watershed and LULC patterns will be significant for the sustainable management of the arid regions in northwest China.

Keywords: LULC; Hydro-chemical characteristics; GIS; correlation coefficient; Step-wise linear multiple regressions

1. Introduction

Water quality is of great importance to the study of water resources in arid regions. Hydro-chemical characteristics may help understand the environmental and geological conditions, i.e., the controlling factors in which waters are formed [1]. Accurate information on the spatial distribution of surface water characteristics is imperative for assessment of environmental monitoring, land surface water management as well as watershed changes [2,3]. In particular, there is little or no information on river hydro-chemical characteristics in arid zones in China. Formal references on its hydro-chemical characteristics are also scarce in China [4,5]. Generally, stream water chemistry is controlled by numerous natural, e.g., weathering, precipitation inputs, and anthropogenic factors. Hydro-chemical characteristics have deteriorated noticeably in many countries in the past decades due to poor land use practices [6–8], which resulted in the material sources and evolution processes of chemical composition and the content of different ions are being very complicate [1].

Land use/cover (LULC) patterns have important effects on the quality of river aquatic systems within a watershed [9–11]; for example, the development of a watershed from the dominant LULC to an artificial land system frequently reduces the base flow, which is a result of changing the groundwater flow pathways to surface water bodies [12]. Numerous problems related to hydro-chemical characteristic are caused by human-driven changes in LULC [13–16], because these anthropogenic activities are directly reflected in LULC patterns in the river basins [17]. Recently, many studies around the world have shown that LULC has a strong impact on the quantity and quality of the stream water in watersheds [18–20], and significant correlations exist between LULC patterns and hydro-chemical characteristic parameters [21–23]. For example, strong relationships have been found between increasing extent of agricultural development in catchments and declining water quality of streams [24]. Donohue et al. [25] associated land cover characteristics with the ecological status and identified that urban, pasture lands, and arable were dominant factors impacting the ecological quality of river streams. Lee et al. [9] indicated that water quality of reservoirs in South Korea was closely associated with urban, agricultural, and forest areas.

Meanwhile, numerous researchers in China have examined the relationship between LULC and hydro-chemical characteristic, but few of these studies have included the typically arid areas in Ebinur Lake Watershed. Zhang et al. [26] reported that LULC significantly impacted the hydro-chemical ecosystem in this area. Given seasonal differences, the unbalanced distribution of precipitation amount results in an apparent variation in surface runoff and further imbalance in the spatial distribution of hydro-chemical characteristics in the research zone [27–29]. During the wet season (May) in Ebinur Lake Watershed, melted water from mountain ice and snow is collected, which promotes flow in Bortala River and Jing River, thereby resulting in a significant increase in surface runoff. During the dry season, however, elements in water can be partially absorbed and purified to a certain extent because of the rise in temperature and the growth of aquatic plants in rivers and lakes. Therefore, a significant change in surface runoff and seasonal change in the research zone are important factors that result in noticeable differences in the spatial distribution characteristics of hydro-chemical characteristics during the wet and dry seasons. In this study, we performed a comparative examination of LULC in the target area using GIS procedures and RS satellite images in May and September of 2014 to assessment of the impacts of LULC on the hydro-chemical characteristics in Ebinur Lake main tributaries. The main objectives of this study are to: (1) Explore the spatial patterns of hydro-chemical characteristics during rainy and dry seasons; (2) Analyze LULC changes during rainy and dry seasons; and (3) Study LULC patterns' effects on hydro-chemical characteristics during dry and rainy seasons.

2. Study Area

Ebinur Lake Watershed is located at 43°38′~45°52′ N and 79°53′~85°02′ E in northwest Xinjiang Uygur Autonomous Region of the People's Republic of China (Figure 1). The total area of the Watershed is 50,621 km^2, which consists of mountains, plains and water bodies [30]. Ebinur Lake Watershed was once fed by 12 branch rivers from the Bortala, Jing and Kuytun River systems. The Watershed is now mainly recharged by alpine glacier melt water and mountain precipitation. Total runoff is 37.46×10^8 m^3/year [31]. Due to environmental changes and human activities (i.e., agricultural development in oases), some rivers have gradually lost their hydraulic connections, with only Bortala River and Jing River now feeding Ebinur Lake. Ebinur Lake is a closed saline lake with the water salinity from 80 g/L to 120 g/L; sodium sulfates and chlorides predominate in the composition of dissolved salts [32]. At the beginning of the twentieth century, the area of the lake was about 1300 km^2. At present time (late September 2014), the area of the lake is only about 420 km^2 as seen in the satellite image. The surface from the water evaporation represents a vast bare solonchak with a high amount of salts (more than 40% in the upper 2 cm and 10–30% in the lower layer of 2–5 cm) made up of predominantly sodium sulfates and chlorides [33].

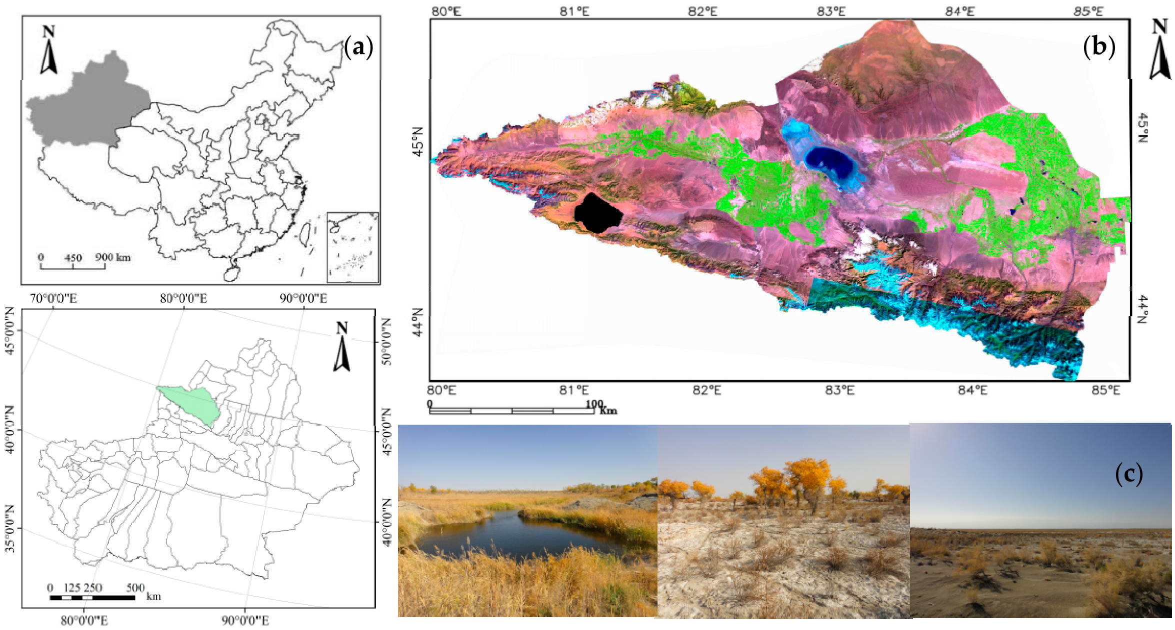

Figure 1. Location and Landscape Photos of the Study Area: (**a**) The water environment of Ebinur Lake Watershed; (**b**) The salinized land of Ebinur Lake Watershed; and (**c**) Ganjia Lake Haloxylon Forest National Nature Reserve.

3. Satellite Image Acquisition and Processing

Twelve Landsat OLI images were acquired in May and September of 2014 over Ebinur Lake Watershed (Table 1). Data were downloaded from USGS website in level 1G product [34] with a spatial resolution of 30 m. Furthermore, all images were selected with less than 20% cloud cover and geo-referenced images were obtained to generate the entire study area images based on a mosaic tool [35]. In this study, the images were acquired in different seasons. Thus, it was crucial to make an atmospheric correction and radiometric normalization to all images to eliminate effects of haze and dust as well as solar angle variations. Geometric rectification using 1:50,000 topographic maps was performed on all remotely sensed images. A second order polynomial fit was applied to correct remotely sensed images using 50 ground control points (GCPs) selected from topographic maps, with a root mean square error (RMSE) less than 0.5 pixels. Radiometric calibration was carried out using the Environment for Visualizing Images software (ENVI Version 5.0 (Exelis Visual Information Solutions, Boulder, CO, USA)) [36]. The atmospheric correction for the OLI images was undertaken by using the Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercube (FLAASH) method of ENVI 5.0 [36].

Table 1. Landsat OLI Coverage of Ebinur Lake Watershed in May and September of 2014.

Month	Path	Row	Sensor	Acquisition Date
May	145	29	OLI	9 May 2014
	146	28	OLI	16 May 2014
	146	29	OLI	16 May 2014
	147	29	OLI	7 May 2014
	148	29	OLI	14 May 2014
September	145	29	OLI	14 September 2014
	145	30	OLI	14 September 2014
	146	28	OLI	21 September 2014
	146	29	OLI	21 September 2014
	147	29	OLI	12 September 2014

4. Water Sampling Collection

The surface water quantity in March, April and May are greater than that in June, July, August, September and October in Ebinur Lake Watershed. Thus, we regard May as in rainy season and September in dry season [37]. Water samples were collected in two field surveys in the Watershed during the rainy (May) and dry (September) seasons in 2014. In the last 30 years, cotton has been the major crop in the Watershed with an annual harvest of 7.5×10^7 kg [38]. Urban residents around the Watershed live primarily on agriculture and husbandry. No heavy industry is present. Therefore, point-source pollution from industrial wastewater was not considered in this study. Based on on the field survey, sampling points were set in the main entrances and exits of lake, the confluence of rivers, the typical area such as farmland around, etc. Our samples were collected from the farmland in Jinghe County and Tuotuo Village around Ebinur Lake, a national ecological zone in Ebinur Lake Bird Isle, and the Ganjia Lake Haloxylon Forest National Nature Reserve. We obtained altogether 56 and 57 samples for rainy and dry seasons, respectively. The sampling points were separated at approximately 5-km intervals along the horizontal gradient from west to east and samples were taken both from mainstreams and tributaries. Ten representative parameters were chosen from the measurements, namely the pH, EC, SO_4^{2-}, HCO_3^-, Cl^-, Mg^{2+}, Na^+, Ca^{2+}, K^+ and mineralization, with the last being variable with the content of ions, molecules and compounds. In the field sampling, water was sampled at the depth of 0.5 m below the surface water using previously acid-washed high density polyethylene (HDPE) bottles and the environment of sampling points was recorded. In situ parameters such as pH, EC, mineralization, etc. were measured with portable electronic meters immediately in the field after sampling. All samples were packed and stored in refrigerated containers, tried to slow the progress of the physical function and chemical action before being sent to the labs for further measurement or data collection. In the laboratory, measurement parameters were SO_4^{2-}, HCO_3^-, Cl^-, Mg^{2+}, Na^+, Ca^{2+} and K^+.

The value of pH was measured using pH-40A portable pH acidity meter (Hangzhou Lohand Biological Co., Ltd., Hangzhou, China); EC was determined by the conductivity meter (Sensortechnik Meinsberg, Bad Pyrmont, Germany); Mineralization was determined using gravimetric method; SO_4^{2-} was determined by EDTA-indirect titrimetry; HCO_3^- was determined with the double indicator neutral method; Cl^- was determined by $AgNO_3$ titration; Mg^{2+} and Ca^{2+} were determined with the EDTA complexometric method; and Na^+ and K^+ were determined by the flame photometry. The determination of water parameters in the laboratory complied with national standard methods defined in [39,40] .

5. Spatial and Statistical Analyses

5.1. Classification System for LULC Patterns in Ebinur Lake Watershed

Land use maps interpreted from 2014 Landsat OLI images (30 m resolution) were used to measure the LULC composition in the Watershed using ArcGIS version 10.0. Many land cover classification methods have been proposed in recent years [41,42]. Compared with these novel classifiers, the decision tree (DT) classifier has generally been used because of its nonparametric and characteristic tree structure [43,44]. DT is made up of a series of binary decisions that are used to determine the correct category for each pixel. The DT method also is sufficiently robust to deal with the loss caused by incomplete remote data. Thus overcome the limitation of the data distribution requirements with the maximum likelihood method [45]. Thus, in this paper, DT was applied to Landsat OLI images which had been acquired in May and September 2014.

The LULC was classified into five categories based on the national land resource classification system, on the field survey that had been conducted many times to set up the interpretation signs [46], and on the actual LULC patterns of Ebinur Lake Watershed: (1) Farmland, mostly planted with maize, cotton, grape and medlar; (2) Forest–grassland, including forest land, grassland and pasture for livestock; (3) Water body, including reservoir, river, and pond; (4) Salinized land, including slight saline land, moderate saline land and heavy saline land (statistics indicate that soil salinization in Ebinur Lake area mainly occurs in Bortala River, Jing River, the villages and towns surrounding Ebinur Lake, downstream of Daheyanzi River, and north of Bole); (5) Others, including gravel, bare ground, and bare rock. Google Earth was used to verify LULC patterns.

5.2. Accuracy Assessment

In this study, the Kappa coefficient was used for a quantitative assessment, which is one of the most widely used methods in the assessment of classification accuracy [47]. Using stratified sampling methods, fifty samples were selected in Ebinur Lake Watershed as the "ground-truthing" pixels by GPS positioning. The LULC classification accuracy was evaluated by the overall accuracy and the Kappa coefficient based on the error matrix [48]. The Kappa coefficient was calculated as:

$$Kappa = \frac{P\sum_{i=1}^{n} P_{ii} - \sum_{i=1}^{n}(P_{i+} \times P_{+i})}{P^2 - \sum_{i=1}^{n}(P_{i+} \times P_{+i})} \tag{1}$$

where P is the total number of pixels from the reference data; P_{ii} is the total number of correct pixels from the category; P_{i+} is the total number of pixels for the category derived from the classified data; P_{+i} is the total number of pixels for the category derived from the reference data; and n is the total number of categories. In this study, the total accuracy and Kappa coefficient for classification were equal to 91.2% and 0.8848 in the rainy season, and 94.5% and 0.9335 in the dry season, respectively.

5.3. Spatial Analysis

Firstly, we use stratified sampling methods to select the points in each LULC patterns by ArcGIS and collected the ground reflection value of every point to analyze the relationship between the ground reflection value of LULC patterns and the hydro-chemical characteristic parameters. Due to the differences of the spatial distribution of LULC patterns, 30 points are selected in each LULC patterns surrounding the actual water sampling points. Then, the ground reflection value of each LULC pattern was extracted, and the correlation between the ground reflection values of different LULC patterns and hydro-chemical characteristic parameters was analyzed. In addition, this study was based on the DEM and stream networks of the Watershed, and delineated six zones to analyze the distribution characteristics of physicochemical parameters of hydro-chemical characteristics and its relationship with LULC patterns in different zones during dry and rainy seasons. Ebinur Lake Watershed was divided into six zones: (1) Zone 1, including Wenquan County and Bole city, mainly from the upstream to the middle part of Bortala River; (2) Zone 2, including Jinghe County and Jinghe Oasis, mainly farmland; (3) Zone 3, mainly including Ebinur Lake, a national ecological zone in Ebinur Lake Bird Isle and the Ganjia Lake Haloxylon Forest National Nature Reserve; (4) Zone 4, including reservoirs and farmland in Wusu County; (5) Zone 5, mainly including farmland in Wusu County; and (6) Zone 6, including Kuitun River and nearby mountains. Meanwhile, because of the uneven distribution of water sampling points in six zones, using the zone to set up the relationship between various LULC patterns and hydro-chemical characteristics parameters harbors some uncertainties. Thus, this study set up 100 m, 200 m, 300 m, 400 m, 500 m, and 600 m buffers around water sampling points using ArcGIS spatial analysis tools. Preliminary analysis found that the relationship between various LULC patterns and hydro-chemical characteristics parameters were better under the 500 m buffer. Thus, land use/cover patterns and their influences on hydro-chemical characteristic were only analyzed under the 500 m buffer during dry and rainy seasons.

5.4. Statistical Analysis

For hydro-chemical characteristic properties, single factor analysis of variance (ANOVA test) with the post-hoc test (least-significance difference, LSD). Li et al. [49] used to analyze the variance in hydro-chemical characteristic parameters in different sites at a significance level of $p < 0.05$. Factor analysis (FA) was used to identify the change of hydro-chemical characteristic factors that affected hydro-chemical characteristics during rainy and dry seasons. Before FA was performed, the hydro-chemical characteristic data were initially standardized by *z*-scale transformation to avoid misclassification because of the wide differences in data units and dimensionality [39]. Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests were conducted to measure the adequacy of the sampling data for FA. For the FA, a given variable was considered to be moderately important when PC loadings are about 0.50 and 0.75 and to be an important contributor to a PC if its absolute loading exceeds about 0.75 [50]. Correlations between LULC patterns and hydro-chemical characteristics parameters were tested using Pearson's correlation coefficients with statistical significance at $p < 0.01$ and $p < 0.05$ levels (2-tailed), respectively. We conducted Stepwise linear multiple regressions, an effective approach to identify significant land use patterns to explain hydro-chemical characteristics variation in a watershed. For the correlation and regression analysis, the one-sample Kolmogorov–Smirnov test was used in testing the normal distribution for all variables [51]. The results showed asymptotic significance (Asymp. Sig.) (2-tailed) values (*p* values) ranging from 0.148 (Mg^{2+}) to 0.939 (pH) and greater than 0.05, suggesting normal distribution. All statistics were calculated by using SPSS 16.0. The conceptual flow chart describing the methodology is shown in Figure 2.

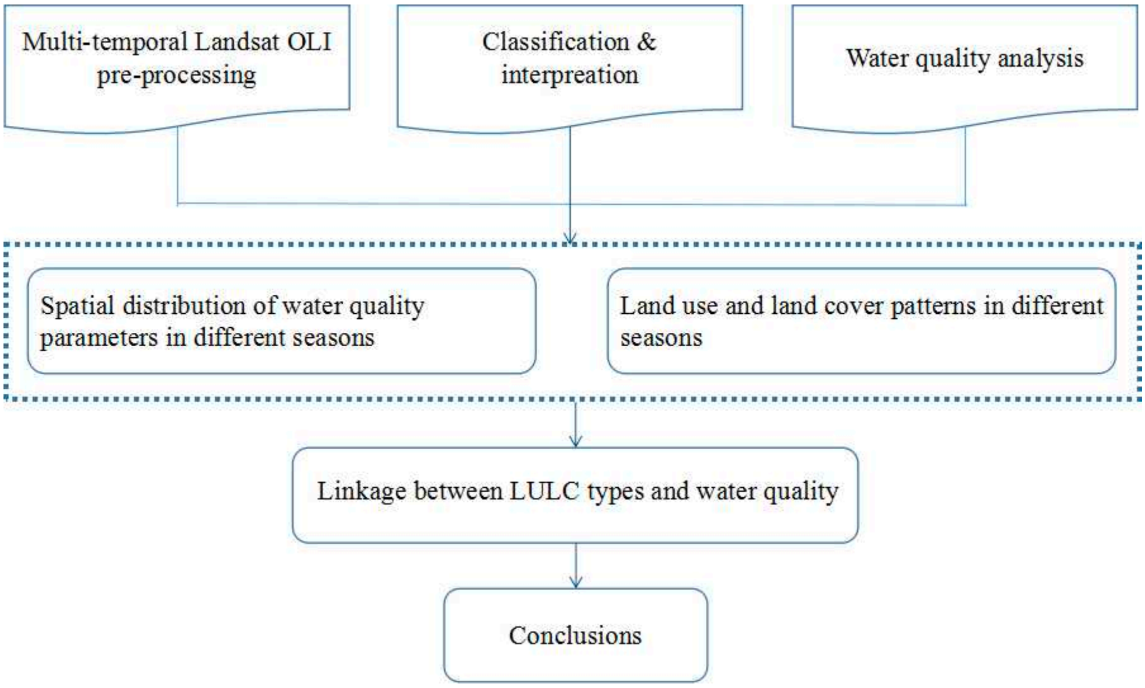

Figure 2. Conceptual model for the methodology.

6. Result and Discussion

6.1. Characteristics of Hydro-Chemical Characteristics

Given seasonal differences, the unbalanced distribution of precipitation results in an apparent variation in surface runoff and further imbalance in the spatial distribution of hydro-chemical characteristics in the research zone [27–29]. Overall, hydro-chemical characteristic parameters changed significantly during rainy and dry seasons (Table 2). In the rainy season, the coefficient of variation (CV) of EC, mineralization, HCO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+ and K^+ exceeded 50%. In the dry season, the CV of Cl^-, SO_4^{2-}, Ca^{2+} and Na^+ exceeded 50%. The results showed that the ion concentration distributes unevenly in the Watershed. During dry and rainy seasons, the results of ANOVA (Table 3) showed that the significant (Sig.) value of pH was greater than the significance level of 0.05, so the distribution of pH was uniform in each zone. pH range was mainly from 7.8 to 8.1. Overall, most of the variables showed significant spatial differences ($p < 0.05$) among different zones in rainy season and less significant differences in dry season. Samples and their physicochemical parameters during dry and rainy seasons in each zone of the Watershed are presented in Tables 4 and 5 and Figure 3. The values of EC, HCO_3^-, Cl^-, Na^+, Ca^{2+} and K^+ were higher in Zone 3, which mainly included Ebinur Lake, a national ecological zone in Ebinur Lake Bird Isle and the Ganjia Lake Haloxylon Forest National Nature Reserve. Zone 3 was a seriously salinized area in the Watershed. The surrounding area of Ebinur Lake was particularly affected by human activities. As a result, the hydro-chemical characteristics in this region were more seriously affected. In addition, the highest value of mineralization, SO_4^{2-} and Mg^{2+} were located in Zone 2, which mainly included the farmland of Jinghe oasis. The low concentration of EC, SO_4^{2-}, Cl^-, Mg^{2+}, Na^+, Ca^{2+} and K^+ were recorded in Zones 1 and 5. The value of mineralization in Zone 5 was higher than that in Zone 4. The low concentration of HCO_3^- was found in Zone 5, which mainly included the farmland in Wusu County.

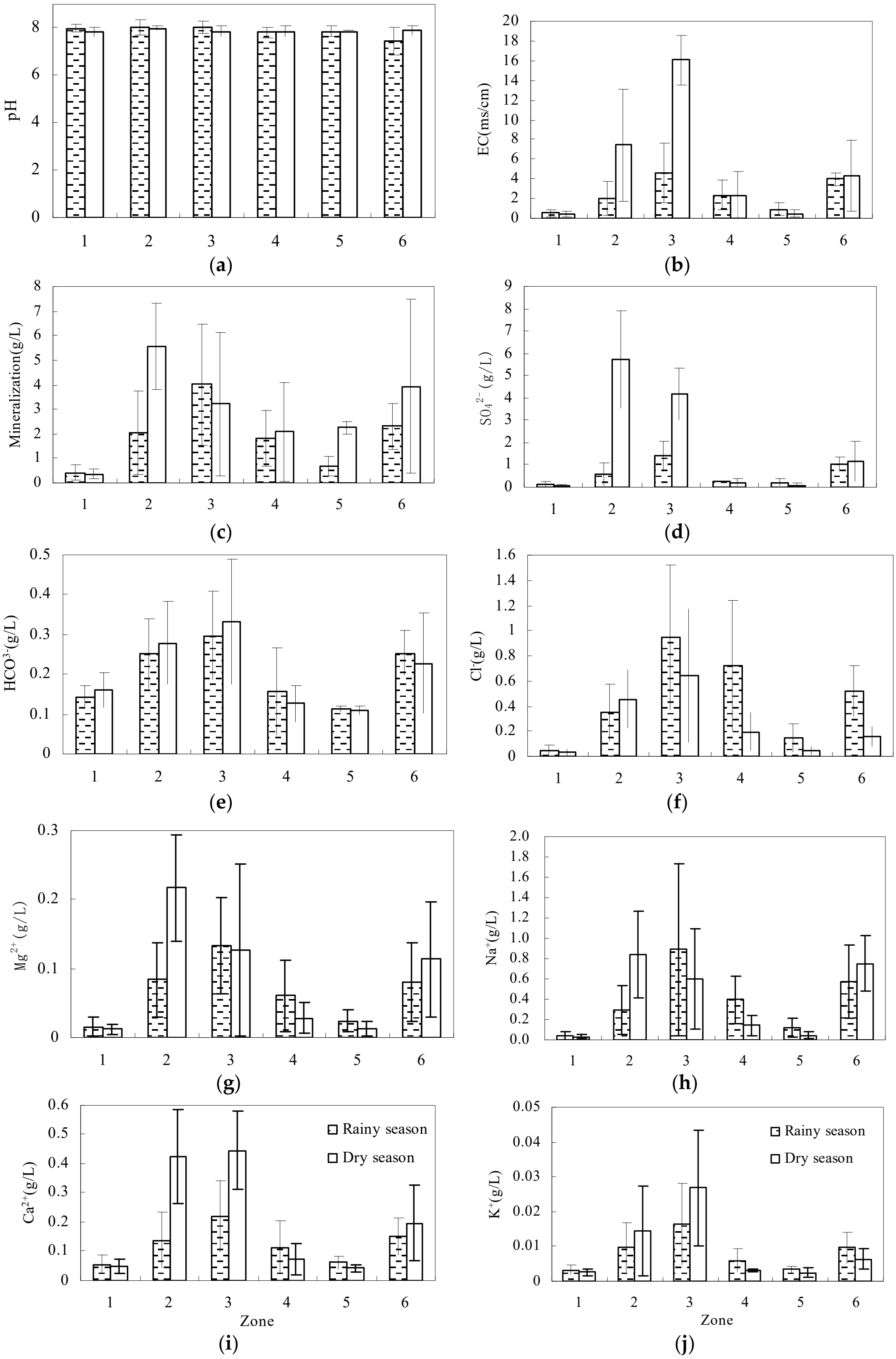

Figure 3. Values (mean ± S.E.) of water parameters (including pH (**a**), EC (**b**), Mineralization (**c**), SO_4^{2-} (**d**), HCO_3^- (**e**), Cl^- (**f**), Mg^{2+} (**g**), Na^+ (**h**), Ca^{2+} (**i**) and K^+ (**j**)) during dry and rainy seasons in different zones of Ebinur Lake Watershed.

Table 2. Summary of hydro-chemical characteristics parameters observations of Ebinur Lake Watershed during rainy and dry seasons.

Seasons	Parameter	Maximum Value	Minimum Value	Mean Value	CV (%)
Rainy season	pH	8.27	7.01	7.58	4.97
	EC (ms/cm)	13.09	0.2	1.37	79.12
	Mineralization (mg/L)	5.01	0.21	1.29	81.98
	HCO_3^- (mg/L)	0.72	0.10	0.28	74.94
	Cl^- (mg/L)	0.72	0.02	0.18	48.44
	SO_4^{2-} (mg/L)	2.31	0.02	0.45	80.06
	Ca^{2+} (mg/L)	0.27	0.01	0.08	67.89
	Mg^{2+}(mg/L)	0.17	0.01	0.07	75.61
	Na^+ (mg/L)	0.57	0.01	0.15	66.29
	K^+ (mg/L)	0.02	0.002	0.008	83.45
Dry season	pH	8.39	7.31	7.88	3.34
	EC (ms/cm)	37.9	0.15	2.73	40.09
	Mineralization (mg/L)	28.47	0.16	2.31	37.68
	HCO_3^- (mg/L)	1.15	0.09	0.21	33.78
	Cl^- (mg/L)	12.87	0.004	0.72	69.16
	SO_4^{2-} (mg/L)	5.16	0.01	0.62	65.64
	Ca^{2+} (mg/L)	2.4	0.03	0.17	57.52
	Mg^{2+} (mg/L)	1.04	0.002	0.08	44.31
	Na^+ (mg/L)	8.19	0.01	0.53	61.28
	K^+ (mg/L)	0.09	0.001	0.01	32.35

Table 3. The statistical results of hydro-chemical characteristic parameters from ANOVA.

Seasons	Parameter	F	*df*	Sig.
Rainy season	pH	0.848	4	0.504
	EC (ms/cm)	6.133	4	0.001
	Mineralization (mg/L)	6.898	4	0.000
	HCO_3^- (mg/L)	6.433	4	0.000
	Cl^- (mg/L)	2.445	4	0.000
	SO_4^{2-} (mg/L)	12.672	4	0.000
	Ca^{2+} (mg/L)	5.220	4	0.002
	Mg^{2+} (mg/L)	5.061	4	0.002
	Na^+ (mg/L)	3.979	4	0.008
	K^+ (mg/L)	4.638	4	0.004
Dry season	pH	1.468	4	0.234
	EC (ms/cm)	0.779	4	0.547
	Mineralization (mg/L)	0.665	4	0.621
	HCO_3^- (mg/L)	5.459	4	0.002
	Cl^- (mg/L)	0.646	4	0.634
	SO_4^{2-} (mg/L)	1.686	4	0.176
	Ca^{2+} (mg/L)	0.824	4	0.519
	Mg^{2+} (mg/L)	2.928	4	0.035
	Na^+ (mg/L)	0.598	4	0.667
	K^+ (mg/L)	1.150	4	0.35

Table 4. The sample quantity in different zones.

Seasons	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Rainy season	9	12	16	9	7	3
Dry season	15	9	10	10	10	3

Table 5. The statistical results of mean ± S.E. in different zones.

Seasons	Parameter	Mean ± S.E.					
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Rainy season	pH	7.99 ± 0.16	8.03 ± 0.34	8.02 ± 0.26	7.81 ± 0.21	7.85 ± 0.22	7.47 ± 0.58
	EC	0.52 ± 0.40	2.05 ± 1.70	4.63 ± 2.98	2.33 ± 1.51	0.93 ± 0.58	3.97 ± 0.68
	Mineralization	0.42 ± 0.33	2.04 ± 1.70	4.02 ± 2.46	1.83 ± 1.12	0.69 ± 0.41	2.30 ± 0.92
	HCO_3^-	0.14 ± 0.02	0.25 ± 0.08	0.30 ± 0.11	0.16 ± 0.10	0.11 ± 0.01	0.25 ± 0.06
	Cl^-	0.05 ± 0.03	0.35 ± 0.22	0.94 ± 0.57	0.72 ± 0.51	0.14 ± 0.11	0.52 ± 0.20
	SO_4^{2-}	0.15 ± 0.13	0.59 ± 0.50	1.41 ± 0.67	0.24 ± 0.03	0.21 ± 0.15	1.00 ± 0.31
	Ca^{2+}	0.06 ± 0.03	0.14 ± 0.09	0.22 ± 0.12	0.11 ± 0.09	0.06 ± 0.02	0.15 ± 0.06
	Mg^{2+}	0.02 ± 0.01	0.08 ± 0.05	0.13 ± 0.06	0.06 ± 0.05	0.02 ± 0.01	0.08 ± 0.05
	Na^+	0.04 ± 0.03	0.29 ± 0.23	0.89 ± 0.84	0.39 ± 0.22	0.12 ± 0.09	0.57 ± 0.35
	K^+	0.003 ± 0.001	0.009 ± 0.006	0.02 ± 0.01	0.006 ± 0.003	0.003 ± 0.001	0.009 ± 0.004
Dry season	pH	7.86 ± 0.20	7.97 ± 0.11	7.85 ± 0.22	7.86 ± 0.24	7.85 ± 0.04	7.90 ± 0.18
	EC	0.41 ± 0.25	7.43 ± 5.71	16.04 ± 2.48	2.35 ± 2.34	0.45 ± 0.34	4.36 ± 3.58
	Mineralization	0.36 ± 0.20	5.55 ± 1.90	3.21 ± 2.90	2.08 ± 1.98	2.25 ± 0.26	3.92 ± 3.54
	HCO_3^-	0.16 ± 0.04	0.28 ± 0.10	0.33 ± 0.15	0.13 ± 0.04	0.11 ± 0.01	0.23 ± 0.12
	Cl^-	0.03 ± 0.02	0.45 ± 0.23	0.64 ± 0.52	0.20 ± 0.15	0.05 ± 0.03	0.16 ± 0.07
	SO_4^{2-}	0.06 ± 0.05	5.74 ± 2.18	4.17 ± 1.15	0.21 ± 0.19	0.09 ± 0.08	1.17 ± 0.90
	Ca^{2+}	0.05 ± 0.02	0.42 ± 0.16	0.45 ± 0.13	0.07 ± 0.05	0.04 ± 0.01	0.20 ± 0.12
	Mg^{2+}	0.01 ± 0.007	0.22 ± 0.08	0.13 ± 0.11	0.03 ± 0.02	0.01 ± 0.008	0.11 ± 0.08
	Na^+	0.03 ± 0.02	0.84 ± 0.42	0.60 ± 0.49	0.14 ± 0.09	0.04 ± 0.03	0.75 ± 0.27
	K^+	0.003 ± 0.001	0.014 ± 0.01	0.027 ± 0.01	0.003 ± 0.001	0.003 ± 0.001	0.006 ± 0.002

Through the factor analysis (FA), we have identified the changes of hydro-chemical characteristic factors that affect hydro-chemical characteristics during dry and rainy seasons. During the rainy season, for instance, the KMO and Bartlett's sphericity test results were 0.803 and 434.174 (df = 45, Sig. < 0.001), respectively. During the dry season, they became 0.818 and 973.172 (df = 45, Sig. < 0.001), respectively. The results show that the water sample data during rainy and dry seasons are suitable for factor analysis.

During the rainy season, the first two rotated factors with eigenvalue of 1 or greater were extracted using Varimax with Kaiser Normalization, explaining 78.9% of the total variance in the hydro-chemical characteristics data set (Table 6). For Factor 1 in the FA study, the important variables were EC, mineralization, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+ and Na^+. The moderately important variable was Cl^-. Similarly, for Factor 2 in the FA study, the results showed that the Watershed was to be of alkaline hydro-chemical characteristics with high loadings on pH, Cl^- and Mg^{2+}. During the dry season, the same two rotated factors with eigenvalue of 1 or greater were extracted using Varimax with Kaiser Normalization, explaining 86.5% of the total variance in the hydro-chemical characteristics data set. For Factor 1 in the FA study, the results showed that, except the pH, the other water parameters were important variables. In Factor 2, the results showed that the Watershed was with high loadings on pH. Overall, the majority of water parameters were moderately important variables in FA during rainy and dry seasons. In recent years, with increasing cultivation in the upstream of Ebinur Lake Watershed, irrigation water usage increased, causing the lake water levels to fall and the lake area to shrink. At the same time, the salt flowing with the river water into Ebinur Lake exacerbated the latter's salinization, resulting in the increase of ion content. Especially, Factor 1 in the FA study during rainy and dry seasons showed that the Ca^{2+} and Mg^{2+} were higher than other cationic contents. Ca^{2+} is easy to form into $CaCO_3$ and then precipitate. With increasing salinization of water, the content of Mg^{2+} greatly exceeds the Ca^{2+}. With the increase of salt content, the ratio of Ca^{2+} and Mg^{2+} becomes smaller and smaller, eventually causing the imbalance of Ca^{2+} and Mg^{2+}, which is harmful to fishery in the Watershed [52].

Table 6. Factor loadings of the 10 variables on rotated component matrix for all hydro-chemical characteristic data during dry and rainy seasons in Ebinur Lake Watershed.

Seasons	**Variables**	**Factor**	
		1	**2**
Rainy season	pH	−0.047	0.875
	EC	0.912	0.317
	Mineralization	0.962	−0.204
	HCO_3^-	0.139	0.569
	Cl^-	0.565	−0.538
	SO_4^{2-}	0.969	−0.027
	Ca^{2+}	0.900	0.006
	Mg^{2+}	0.725	0.562
	Na^+	0.898	0.308
	K^+	0.880	−0.013
	Eigenvalue	6.009	1.877
	% of variance	60.093	18.769
	Cumulative	60.093	78.862
Dry season	pH	−0.036	0.955
	EC	0.912	0.074
	Mineralization	0.899	0.075
	HCO_3^-	0.879	−0.220
	Cl^-	0.869	0.240
	SO_4^{2-}	0.888	−0.171
	Ca^{2+}	0.976	−0.140
	Mg^{2+}	0.971	−0.129
	Na^+	0.910	0.094
	K^+	0.914	−0.185
	Eigenvalue	7.541	1.114
	% of variance	75.410	11.136
	Cumulative	75.410	86.545

6.2. LULC patterns in Different Zones

According to the classification results (Figure 4), we can clearly see that the farmland area increased from May to September as the crops grow in rainy season and become ripe for harvest in dry season. Meanwhile, with a shrinking water area, the salinized land increased in September. Since Ebinur Lake Watershed was characterized by little precipitation, strong evaporation, and much wind [26], higher temperatures cause more evaporation and worsen the arid conditions in the Watershed. Thus, in dry season, combined with a large evaporation, the salt was brought to the surface, causing salinization in the surroundings of Ebinur Lake.

Based on classification, the area of various LULC patterns showed obvious differences in six zones. In Figure 5 and Table 7, compared with the rainy season, the area of farmland obviously increased in each zone in the dry season; the area of forest-grass land and water body in each zone decreased. While the salinized land showed an increasing trend in each zone, the area of bare ground and bare rock in rainy season was less than that in the dry season in Zones 1, 2 and 6, and the area of others was greater than that in the dry season in Zones 3–5. Overall, the area of bare ground and bare rock changed little.

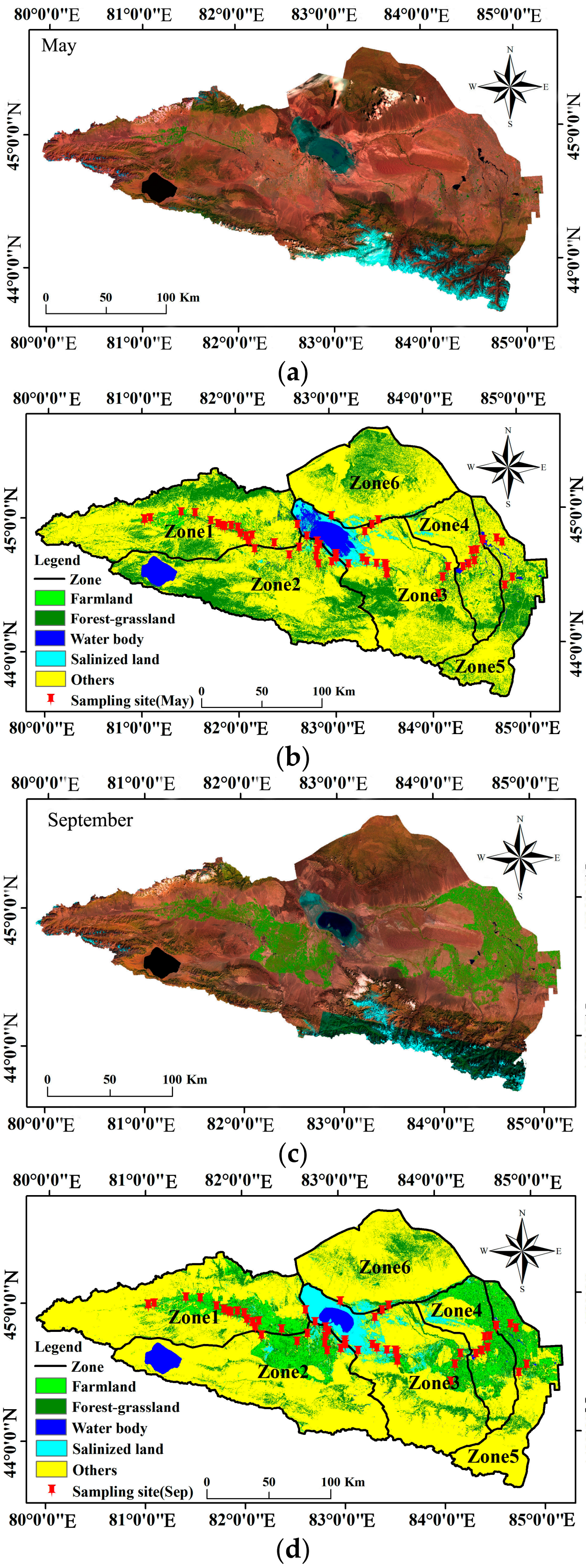

Figure 4. The change of Land use/cover (LULC) in Ebinur Lake Watershed during the rainy and dry seasons in 2014: (**a**) May 2014 remote sensing image; (**b**) LULC classification in May 2014; (**c**) September 2014 remote sensing image; (**d**) LULC classification in September 2014.

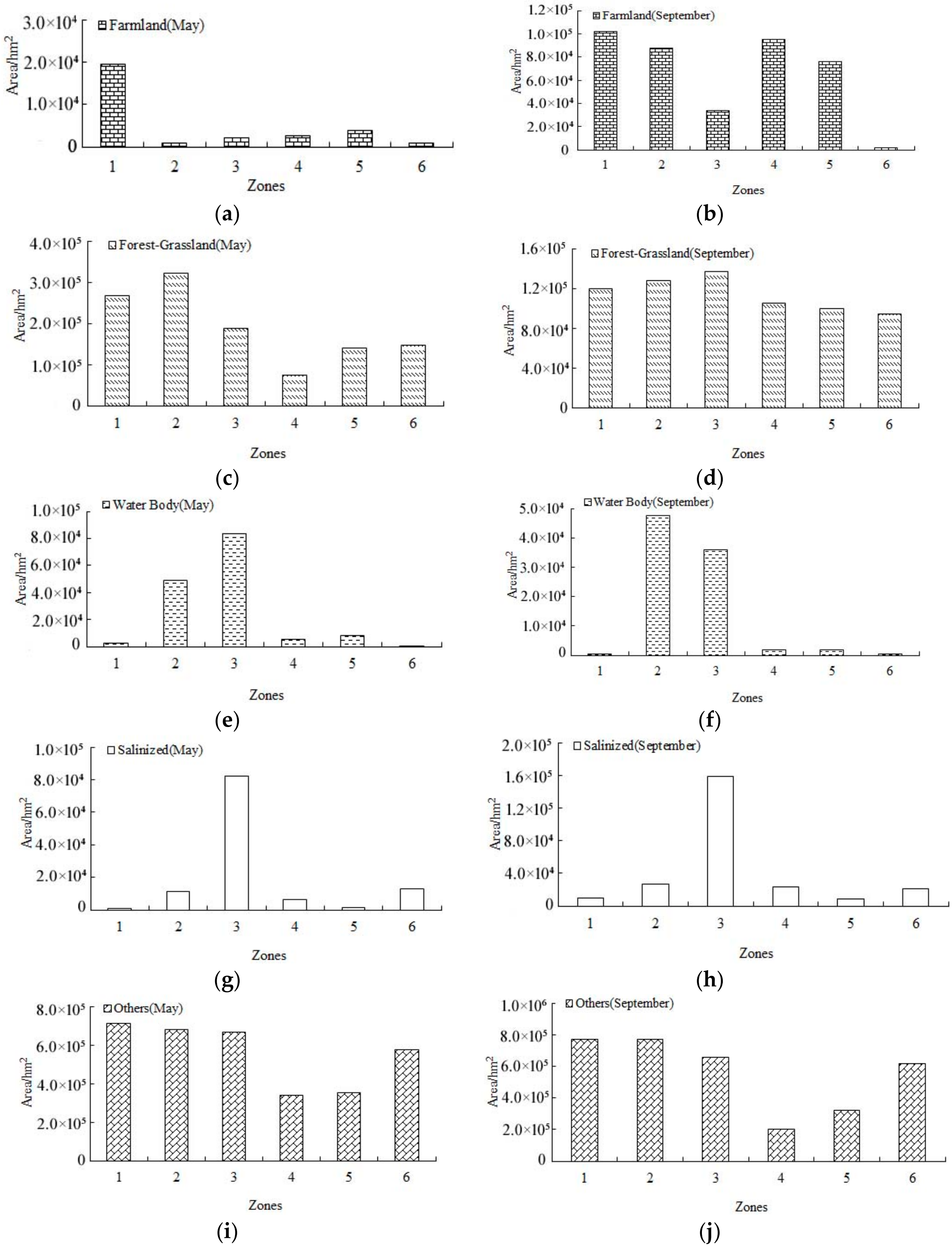

Figure 5. LULC patterns in six zones of Ebinur Lake Watershed: (**a**) Farmland (May); (**b**) Farmland (September); (**c**) Forest–Grassland (May); (**d**) Forest–Grassland (September); (**e**) Water Body (May); (**f**) Water Body (May); (**g**) Salinized (May); (**h**) Salinized (September); (**i**) Others (May); (**j**) Others (September).

Table 7. The area of LULC patterns in six zones of Ebinur Lake Watershed.

Seasons	Land Use/Cover Types	Zone 1 (hm^2)	Zone 2 (hm^2)	Zone 3 (hm^2)	Zone 4 (hm^2)	Zone 5 (hm^2)	Zone 6 (hm^2)
Rainy season	Farmland	19,461.6	960.8	2052.1	2702.5	3852.8	749.7
	Forest-Grassland	267,052.9	321,330.5	188,330.3	74,622.4	140,487.3	147,660.8
	Water Body	2764.6	49,142.0	83,492.4	5256.9	7842.5	304.9
	Salinized land	758.3	11,485.2	81,888.5	6179.5	1132.2	12,830.4
	Others	712,495.2	678,230.5	666,863.9	337,828.7	354,084.4	573,920.7
Dry season	Farmland	101,825.6	87,357.9	33,521.8	94,896.24	76,043.8	1844.1
	Forest-Grassland	119,773.8	127,749.9	136,417.0	104,647.4	99,783.9	94,343.7
	Water Body	546.7	47,523.4	35,940.3	1941.5	1981.6	415.3
	Salinized land	9908.7	26,646.24	158,122.6	23,049.9	8291.4	21,168.2
	Others	770,489.7	771,883.5	658,624.3	202,054.6	322,959.8	617,694.6

Overall, LULC patterns are conspicuously different in the six zones (Figure 6). In the rainy season, large forest-grassland areas, over 50% of total land area, are distributed in Zone 4. Water areas have extensive distributions from 3.9% (Zone 5) to 8.1% (Zone 3). Around Ebinur Lake and in the Bohe and Jinghe tributaries, salinized land area ranges from 8.1% (Zone 2) to 15.7% (Zone 3). Gravel, bare ground and bare rock also represent a big proportion in Zones 1, 4 and 6, ranging from 53.1% (Zone 6) to 66.5% (Zone 4) of their respective drainage areas.

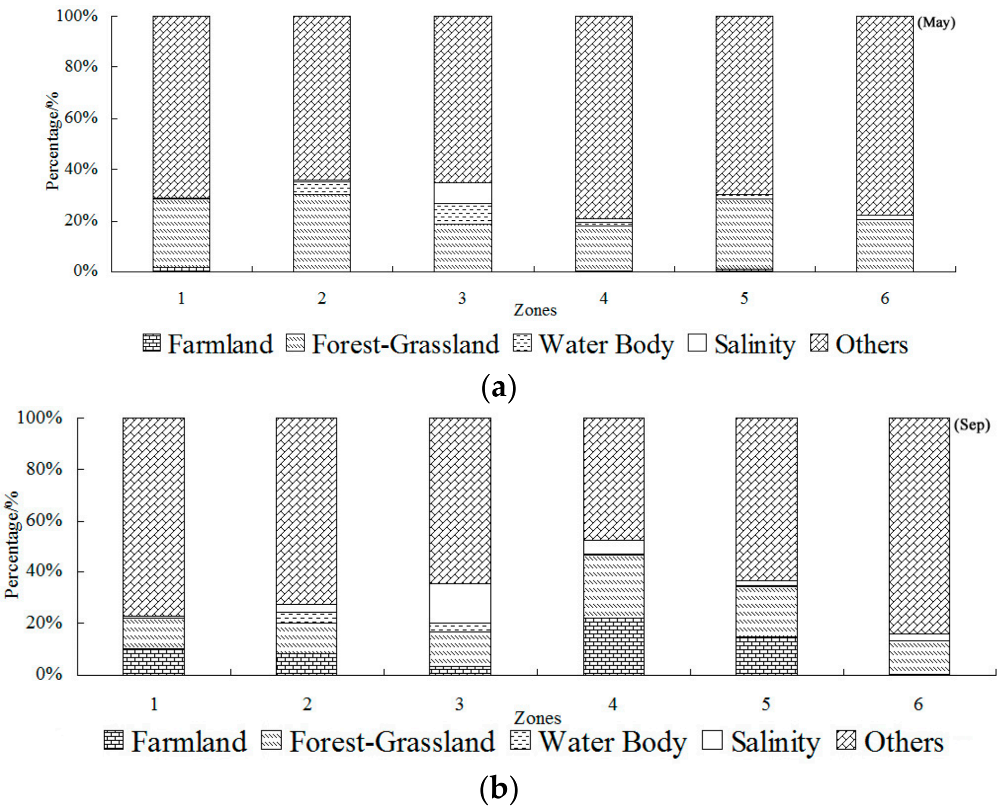

Figure 6. Composition (%) of land use patterns in 6 different zones in Ebinur Lake Watershed: (**a**) Composition (%) of land use patterns in May 2014; (**b**) Composition (%) of land use patterns in September 2014.

In dry season, farmland area ranges from 8.1% (Zone 2) to 22.9% (Zone 4). Most forest-grassland areas, over 20% of the total land area, are distributed in Zones 1, 2, 4 and 5. Water body is mainly found in Zones 2 and 3. Due to human activities such as farming irrigation, salinized land was concentrated in large farmland areas. Meanwhile, reduced precipitation in dry season leads to the contraction of

Ebinur Lake and expansion of the salinized land around it. Large areas of salinized land are mainly found in Zone 2 and 3. In dry season, the phenomenon of salinization was more serious than in rainy season. Salinized land mainly contained the sodium, calcium, magnesium carbonate, sulfate and chloride. The proportion of salinized land is the primary predictor for mineralization values during the dry season. Bare ground and bare rock are at a high percentage and over 50% are distributed in Zones 1 and 6.

6.3. Linkage between LULC Patterns and Hydro-Chemical Characteristics

First, we extracted the ground reflectance value of various LULC patterns and analyzed the correlation between the ground reflectance values and hydro-chemical characteristics (Table 8).

Table 8. Correlation between the ground reflectance and hydro-chemical characteristics during rainy and dry seasons.

Seasons	Parameter	Farmland	Forest-Grassland	Water Body	Salinized Land
Rainy season	pH	0.298	−0.306	0.608 *	−0.210
	EC	−0.425	0.085	0.449	−0.174
	Mineralization	−0.330	0.106	0.448	−0.182
	HCO_3^-	−0.016	0.700 **	0.948 **	−0.236
	Cl^-	−0.713 *	0.054	0.439	−0.181
	SO_4^{2-}	−0.138	0.193	0.450	−0.184
	Ca^{2+}	−0.080	0.178	0.552	−0.161
	Mg^{2+}	−0.107	0.292	0.458	−0.198
	Na^+	−0.571	0.077	0.441	−0.161
	K^+	−0.095	0.110	0.475	−0.191
Dry season	pH	−0.052	0.196	0.224	−0.705
	EC	0.333	−0.093	−0.309	0.965 **
	Mineralization	0.323	−0.014	−0.285	0.965 **
	HCO_3^-	0.176	0.503 *	−0.064	0.850 **
	Cl^-	0.327	−0.168	−0.360	0.967 **
	SO_4^{2-}	0.327	0.276	−0.276	0.959 **
	Ca^{2+}	0.319	0.150	−0.252	0.926 **
	Mg^{2+}	0.317	0.159	−0.261	0.967 **
	Na^+	0.324	−0.103	−0.314	0.965 **
	K^+	0.217	0.552 *	−0.308	0.968 **

Note: * $p < 0.05$ (2-tailed), ** $p < 0.01$ (2-tailed).

The result showed that the ground reflectance values of various LULC patterns had good correlation with hydro-chemical characteristic parameters. Especially in rainy season, the result showed that the ground reflectance value of farmland had was negatively correlated with Cl^-. Usually, Cl^- was affected by fertilizer and organic fertilizer around the farmland. The soil salinity is higher in Xinjiang, chlorine salt in soil salt is greater. In recent years, with the development of the soil experiments on fertilizer formula, the chloride ion content in the fertilizer is generally high [53]. In rainy season, the crops in the study area had not yet started to grow, so the fertilizer had less influence on Cl^-. At the same time, the ground reflectance value of water body is related to pH under the significance level of 0.05. Meanwhile, the relation between the ground reflectance value of salinized land and hydro-chemical characteristics parameters were not significant, because the salinized land was not the main factor affecting hydro-chemical characteristics parameters in rainy season. In dry season, the ground reflectance values of salinized land had great impact on hydro-chemical characteristic parameters. With the decrease of the water area, the salinized land increased in dry season. Because it had higher reflectivity, the ground reflectance values of salinized land had great influence on hydro-chemical characteristic parameters.

Then, we discussed and analyzed the correlation between hydro-chemical characteristics and LULC patterns at different zones during rainy and dry seasons. The results are presented in Table 9.

During the rainy season, the water body and salinized land were significantly related to the majority of water parameters under the significance level of 0.01 and 0.05. Due to the precipitation and melt water, surface runoff was relatively rich lead to some ion as rivers into reservoir and Ebinur Lake, placing the area of water body at high relevance with hydro-chemical characteristics parameters. Due to salinized land mainly contained the sodium, calcium, magnesium carbonate, sulfate and chloride, it had a positive correlation with hydro-chemical characteristics parameters.

During the dry season, forest-grassland displayed a negative correlation with EC under the significance level of 0.01. At a significance level of 0.05, water body exhibited an obvious positive correlation with HCO_3^-. The water body exhibited an obvious positive correlation with EC, Ca^{2+} and K^+ under the significance level of 0.01. Due to decrease of rainfall, irrigation, surface runoff, the area of lake, etc. largely led to the increase in ion content, which had great influence on hydro-chemical characteristics parameters. At a significance level of 0.05, salinized land exhibited a significant positive correlation with mineralization, HCO_3^- and Cl^-. At a significance level of 0.01, salinized land exhibited a significant positive correlation with SO_4^{2-}, Ca^{2+}, Mg^{2+} and Na^+. In dry season, the phenomenon of salinization was more serious than in rainy season. Thus, the salinized land had greater influence on hydro-chemical characteristic parameters. The bare ground and bare rock had significant positive correlations with the EC and K^+ under the significance level of 0.05. Overall, the area of water body (lake, reservoir, pond, etc.) and salinized land had great influence on hydro-chemical characteristics parameters, followed by bare ground and bare rock.

Table 9. Correlation between LULC patterns and hydro-chemical characteristics at different zones during rainy and dry seasons (56 points in rainy season and 57 points in dry season).

Seasons	Parameter	Farmland	Forest-Grassland	Water Body	Salinized Land	Others
Rainy season	pH	0.155	0.866	0.684	0.480	0.965 **
	EC	−0.591	−0.161	0.863	0.925 *	0.176
	Mineralization	−0.598	−0.047	0.911 *	0.922 *	0.261
	HCO_3^-	−0.452	0.388	0.959 **	0.815	0.597
	Cl^-	−0.601	−0.405	0.654	0.780	−0.061
	SO_4^{2-}	−0.449	0.128	0.971**	0.976 **	0.437
	Ca^{2+}	−0.584	0.031	0.932 *	0.913 *	0.323
	Mg^{2+}	−0.629	0.064	0.936 *	0.881 *	0.319
	Na^+	−0.552	−0.197	0.846	0.941 *	0.164
	K^+	−0.529	0.148	0.974 **	0.930 *	0.428
Dry season	pH	−0.372	0.228	0.349	0.721	−0.191
	EC	−0.119	−0.858 **	0.827 **	0.783	0.942 *
	Mineralization	0.026	−0.298	0.423	0.887 *	0.243
	HCO_3^-	−0.410	−0.669	0.951 *	0.909 *	0.788
	Cl^-	−0.131	−0.740	0.807	0.880 *	0.837
	SO_4^{2-}	−0.319	−0.459	0.791	0.926 **	0.514
	Ca^{2+}	−0.276	−0.634	0.858 **	0.975 **	0.706
	Mg^{2+}	−0.328	−0.321	0.716	0.982 **	0.379
	Na^+	−0.290	−0.426	0.757	0.993 **	0.493
	K^+	−0.168	−0.850	0.859 **	0.820	0.920 *

Note: * $p < 0.05$ (2-tailed), ** $p < 0.01$ (2-tailed).

Then, the buffer zones were analyzed in terms of LULC patterns and their influences on hydro-chemical characteristics during dry and rainy seasons. The results showed significant correlations between LULC patterns and hydro-chemical characteristics during the dry and rainy seasons in Ebinur Lake Watershed (Table 10). Forest-grassland, salinized land and water body are associated with most hydro-chemical characteristic variables during both rainy and dry seasons in the Watershed. During the rainy season, because the crops in the study area had not yet started to grow, Haloxylon forest, Natural Populus euphratica and grassland more obviously influence hydro-chemical characteristics than farmland. The proportions of forest-grassland are positively correlated with pH ($p < 0.01$), EC ($p < 0.01$), Mg^{2+} ($p < 0.05$) and Na^+ ($p < 0.01$) and negatively related with mineralization,

Cl^- and Ca^{2+} ($p < 0.01$). The water body is significantly related to most physicochemical variables ($p < 0.01$ or $p < 0.05$) except Ca^{2+}, Mg^{2+} and K^+. Except the HCO_3^-, SO_4^{2-}, Ca^{2+} and K^+, the salinized land shows significant positive correlations with the other hydro-chemical characteristics parameters.

During the dry season, farmland predicts more hydro-chemical characteristic variables than during the rainy season because of intensive fertilization and agricultural runoff [10,13,54]. The results show that the proportion of farmland is positively correlated with pH ($p < 0.01$) and negatively related with EC, mineralization, Cl^-, Ca^{2+} and Na^+ ($p < 0.01$). Forest-grassland displays significant positive correlations with pH, EC, mineralization, Cl^- and Na^+ ($p < 0.01$), and negatively correlations with Ca^{2+} ($p < 0.01$). Water body in different zones is positively correlated with EC, mineralization, SO_4^{2-}, Ca^{2+}, Mg^{2+} and K^+ ($p < 0.01$), and negatively related with pH. Except the HCO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+} and K^+, the salinized land shows positive correlations with other hydro-chemical characteristics parameters.

Table 10. Correlation between LULC patterns and hydro-chemical characteristics in the 500 m buffers during rainy and dry seasons (56 points in rainy season and 57 points in dry season).

Seasons	Parameter	Farmland	Forest-Grassland	Water Body	Salinized Land	Others
Rainy season	pH	0.586	0.882 **	−0.758 **	0.596 *	0.517 *
	EC	−0.373	0.909 **	0.903 **	0.492 *	0.034
	Mineralization	−0.375	−0.915 **	0.962 **	0.518 *	0.224
	HCO_3^-	−0.242	0.017	0.560 *	0.323	0.195
	Cl^-	−0.276	−0.872 **	0.855 **	0.915 **	0.160
	SO_4^{2-}	−0.327	−0.589 *	0.791 **	0.433	0.200
	Ca^{2+}	−0.403	−0.618 **	0.432	0.321	0.373
	Mg^{2+}	−0.275	0.534 *	0.357	0.595 *	0.284
	Na^+	−0.341	0.675 **	0.922 **	0.485 *	−0.033
	K^+	−0.113	−0.087	0.233	0.341	0.342
Dry season	pH	0.959 **	0.645 **	−0.800 **	0.688 **	0.742 **
	EC	−0.751 **	0.864 **	0.958 **	0.800 **	−0.010
	Mineralization	−0.755 **	0.725 **	0.606 **	0.827 **	−0.057
	HCO_3^-	−0.356	−0.037	−0.210	0.301	−0.128
	Cl^-	−0.590 **	0.889 **	0.420	0.326 *	0.132
	SO_4^{2-}	−0.264	−0.038	0.764 **	−0.037	−0.096
	Ca^{2+}	−0.583 **	−0.806 **	0.743 **	−0.097	−0.145
	Mg^{2+}	−0.216	0.065	0.760 **	0.102	−0.069
	Na^+	−0.773 **	0.767 **	0.732 **	0.444 **	0.064
	K^+	−0.102	−0.045	0.352	−0.057	0.140

Note: * $p < 0.05$ (2-tailed), ** $p < 0.01$ (2-tailed).

Stepwise linear multiple regressions models create a "goodness of fit" (R^2 values > 0.50) [55]. EC, HCO_3^-, and SO_4^{2-} during the dry and rainy seasons are predicted based on the proportions of water body (Table 11). During the rainy season, pH, mineralization and Ca^{2+} are defined by forest-grassland, while the Cl^- and Mg^{2+} are defined by salinized land. During the dry season, pH and Na^+ are estimated based on farmland, whereas Cl^- and Ca^{2+} are estimated based on forest-grassland. Specifically, mineralization is explained by salinity during the dry season.

Yan et al. [56] discussed the formation of Ebinur Lake and its evolution process from the point of farmland, livestock, population and industry. His study gave preliminary analysis on the shrinking of the area of Ebinur Lake and the changing of watershed ecological environment over the recent 40 years. The results showed that the water consumption in Ebinur Lake area was negatively related to human activities, increasing vegetation damage caused by human activities, grassland degradation, desertification and salinization. Compared with those a decade ago, the mineralization and the ion content of Ebinur Lake both increased greatly [52]. The phenomenon of water salinization should not be ignored.

Hydro-chemical characteristics is generally linked to LULC in the watershed [57]. Human activities on LULC influence the types and degree of pollution. Therefore, measuring the proportions of certain LULC patterns in a watershed might enable us to conveniently predict hydro-chemical characteristics.

Table 11. Stepwise linear multiple regressions models for hydro-chemical characteristics parameters and LULC patterns during dry and rainy seasons in Ebinur Lake Watershed.

Seasons	Parameter	Independent Variable	Regression Equations	R^2	Sig.
Rainy season	pH	Forest-Grassland	6.765 + 1.784 For-Gra	0.777	<0.001
	EC	Water Body	0.114 + 8.892Wat	0.909	<0.001
	Mineralization	Forest-Grassland	1.744 − 2.387 For-Gra	0.837	<0.001
	HCO_3^-	Water Body	0.147 + 0.438Wat	0.313	0.047
	Cl^-	Salinized land	0.005 + 4.088Sal	0.837	<0.001
	SO_4^{2-}	Water Body	0.139 + 2.123Wat	0.626	<0.001
	Ca^{2+}	Forest-Grassland	0.084 − 0.096 For-Gra	0.381	<0.001
	Mg^{2+}	Salinized land	0.052 + 0.792Sal	0.354	0.012
	Na^+	Water Body	−0.012 + 0.720Wat	0.850	<0.001
Dry season	pH	Farmland	6.880 + 2.141Far	0.919	<0.001
	EC	Water Body	0.144 + 1.867Wat	0.918	<0.001
	Mineralization	Salinized land	0.181 + 0.962Sal	0.684	<0.001
	Cl^-	Forest-Grassland	0.004 + 0.080 For-Gra	0.791	<0.001
	SO_4^{2-}	Water Body	0.023 + 0.859Wat	0.584	<0.001
	Ca^{2+}	Forest-Grassland	0.047 − 0.061 For-Gra	0.650	<0.001
	Mg^{2+}	Water Body	0.011 + 0.106Wat	0.578	0.003
	Na^+	Farmland	0.061 − 0.093Far	0.598	<0.001

7. Conclusions

The results of this study demonstrate the relationships between LULC patterns and water quality of Ebinur Lake Watershed during dry and rainy seasons. The results show that:

(1) During dry and rainy seasons, the distribution of pH was uniform in each zone and the range was mainly from 7.8 to 8.1. Overall, most of the variables showed significant spatial differences ($p < 0.05$) among different zones in rainy season and less significant differences in dry season.

(2) Compared with the rainy season, as crops become ripe in the dry season, the area of farmland significantly increases in each zone; the area of forest-grassland and water body in each zone decreases. While the salinized land shows an increasing trend in each zone, the overall area of others changed little.

(3) During the rainy season, pH, mineralized degree and Ca^{2+} are defined by forest-grassland, while the Cl^- and Mg^{2+} are defined by salinized land. During the dry season, pH and Na^+ are defined based on farmland, whereas Cl^- and Ca^{2+} are defined based on forest-grassland. Especially, mineralized degree is explained by salinized land during the dry season.

From the results, the salinized land had great influence on hydro-chemical characteristics. In recent years, a serious salinization phenomenon existed in study area and the salt as rivers into pond, reservoir, Ebinur Lake, etc., resulting in the increase of ion content. Statistics indicate that salinized land in Ebinur Lake Watershed mainly distributed in Bortala River, Jing River, the surrounding villages and towns of Ebinur Lake, and north of Bole City. Furthermore, salinized land had seriously affected the farming, farmers had to use more fertilizer than before to increase yield. Thus, human activities to some extent affected ion concentration.

Most rivers in Xinjiang are characterized by low water yield, short flow, small water environmental capacity, and poor self-cleaning capability. Thus, scientifically utilizing and protecting the water resources are important issues that could help to achieve the sustainable development in Xinjiang. Thus, scientifically utilizing and protecting the water resources are important issues that could help to achieve the sustainable development in Xinjiang.

This study aims to explore the relationship between LULC and hydro-chemical characteristics. Due to the problem of data quality in the watershed, the data of 2014 were selected to explore the relationship between them. In the follow-up work, we hope to further explore the relationship between LULC and hydro-chemical characteristics in recent years, and compare the effects of land use change on hydro-chemical characteristics.

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Author Contributions: Fei Zhang and Juan Wang conceived and designed the experiments; Hsiang-te Kung performed the experiments; Yan Ren and Yue Zhang analyzed the data; Haiyang Yu contributed reagents/materials/analysis tools; Juan Wang wrote the paper.

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