Change characteristics, influencing factors and suggestions of grassland degradation in adjacent areas of the Qinghai–Tibet Plateau

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Natural grasslands are being progressively degraded around the world due to climate changes and socioeconomic factors. At present, the researches on grassland degradation mainly focused on a wide range, while there was less researches on whether the change characteristics and influencing factors of grassland in adjacent small areas were same. Using Maqu County (MQ), Xiahe County (XH) and Luqu County (LQ) on the eastern QTP as research objectives, this study investigated the changes in grassland area and quality, and analyzed the influences of climate changes and socioeconomic factors during 1980–2018. The results showed that the areas of high and medium coverage grassland in MQ and LQ were decreased continuously with time, while the low coverage grassland areas in 3 counties were increased. In XH, the medium coverage grassland area (except in 2010) was decreased with time, while the high and low coverage grassland areas were increased. The actual net primary productivity (ANPP) of the 3 counties showed a downward trend. In MQ, the total grassland area had extremely significant positive correlation with number of livestock marketing, commodity rate, GDP, primary industry, tertiary industry, household density, junior middle school education and university education. In LQ, the total/high coverage grasslands and number of livestock stock/secondary industry/primary school education/temperature showed significant negative correlation. At the same time, education level was positively correlated with high coverage grassland, and negatively correlated with low coverage grassland in 3 areas. In summary, it is suggested to reduce the local cultivated land area, slow down the development of the primary and tertiary industries in Maqu County; and control the development of industry and the number of livestock stock in Luqu County, which can restore the grassland area and quality. At the same time, it need to improve the education level in 3 areas, which will conducive to the grassland restoration.

Change Characteristics, Influencing Factors and Suggestions of Grassland Degradation in Adjacent Areas of the Qinghai–Tibet Plateau

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Abstract

Natural grasslands are being progressively degraded around the world due to climate changes and socioeconomic factors. At present, the researches on grassland degradation mainly focused on a wide range, while there was less researches on whether the change characteristics and influencing factors of grassland in adjacent small areas were same. This study investigated the changes in grassland area and quality, and analyzed the influences of climate changes and socioeconomic factors during 1980–2018 in Maqu County (MQ), Xiahe County (XH) and Luqu County (LQ) on the eastern QTP. The results showed that the areas of high and medium coverage grassland in MQ and LQ were decreased continuously with time, while the low coverage grassland areas in 3 counties were increased. In XH, the medium coverage grassland area (except in 2010) was decreased with time, while the high and low coverage grassland areas were increased. The actual net primary productivity (ANPP) of the 3 counties showed a downward trend. In MQ, the total grassland area had extremely significant positive correlation with number of livestock marketing, commodity rate, GDP, primary industry, tertiary industry, household density, junior middle school education and university education. In LQ, the total/high coverage grasslands and number of livestock stock/secondary industry/primary school education/temperature showed significant negative correlation. At the same time, education level was positively correlated with high coverage grassland, and negatively correlated with low coverage grassland in 3 areas. In summary, it is suggested to reduce the local cultivated land area,

slow down the development of the primary and tertiary industries in Maqu County; and control the development of industry and the number of livestock stock in Luqu County, which can restore the grassland area and quality. At the same time, it need to improve the education level in 3 areas, which will conducive to the grassland restoration.

Keywords: grassland; climate change; socioeconomic factor; education; suggestion

Introduction

The grassland ecosystem is one of the most widely distributed vegetation types, accounting for about one-fifth of the world's surface area (Zhang et al., 2015). It plays a vital role in maintaining biochemical cycles, regulating climate, preventing desertification, protecting biodiversity, conserving water, and supporting animal husbandry and food production (Fayiah et al., 2022). However, it has been estimated that almost half of the world's grassland ecosystems are being degraded, and almost 5% is experiencing strong to extreme levels of degradation (Gang et al., 2014) —especially on the Qinghai–Tibet Plateau (QTP) (Fassnacht et al., 2015) . A great quantity studies have been carried out to analyze grassland degradation worldwide (Gao et al., 2013). The area of the QTP is approximately 2.5 million km^2, which is nearly 25% of China's total area. Plus, it is high-altitude, and has a long history of grazing (Li and Song, 2021) . As one of the main pastoral regions of China, 60% of the QTP is composed of grassland (Shen et al., 2019) , which serves as an important terrestrial ecological barrier in China (Ren et al., 2016) . Rational utilization of grassland resources and sustainable development of animal husbandry play an important role in maintaining national stability, border security, and grassland culture inheritance on the QTP. Therefore, research on the QTP grassland ecosystem is essential. In turn, there may then be a rise in pest and rodent outbreaks and decreases in biomass, biodiversity, vegetation cover, as well as increases in soil nutrition, soil erosion, sandstorms, greenhouse gases and ecosystem services(Fedrigo et al., 2017; Hu et al., 2017; Hopping et al., 2018). Given its relevance, QTP grassland degradation has become an emerging topic in the fields of environmental protection and grassland management.

Since the vulnerability of ecosystem is generally the result of the combination of natural and human activities, the driving factors behind grassland degradation can be divided into 2 categories: climate changes and socioeconomic factors (Kang et al., 2018; Chuvieco et al., 2014) . However, the relative contributions to grassland degradation remain poorly understood. The grassland ecosystem of the QTP is extremely sensitive to climate changes (Jin et al., 2019). Scientists generally believe that climate changes are important driving factors for the grassland degradation of the QTP, and many experiments have been conducted (Wang et al., 2020) . Numerous studies performed that climate changes are mainly affected by temperature and precipitation (Che et al., 2018) . However, the influencing factors of climate in different areas of grassland are spatially heterogeneous. For example, Li et al. (2019) found that the southern alpine grasslands show a strong response to temperature, whereas the northeast alpine grassland are sensitive to precipitation, and intermediate alpine grassland are mainly affected by the radiation and temperature. Therefore, the impacts of climate change on grassland degradation are different in different areas. Even though certain areas of the QTP have been well studied in terms of grassland degradation, there is a general lack of consideration when it comes to anthropogenic factors (Xia et al., 2021). The QTP's grasslands are experiencing serious degradation at the hands of increased human activities and development. Among these activities, livestock grazing is one of the most important disturbances affecting grassland degradation, as it reduces grassland production and vegetation cover and ultimately leads to a reduction in soil quality (Wang et al., 2020) . However, some studies also suggest that overgrazing is just a symptom, and that changes in grassland management policies and human and social development are important reasons for grassland degradation. In the 1990s, assessments of ecosystem vulnerability increasingly started to consider socioeconomic factors (Qang et al., 1990) , including human activities and development, social and economic developments, and so on. This is key because when the disturbance intensity of socioeconomic factors exceeds the carrying capacity of the ecosystem, the ecological environment will be degraded, resulting in increased grassland degradation (Guo et al., 2016) . Nonetheless, studies on the impacts of socioeconomic factors on grassland degradation – especially the impacts of grassland management policies—are lacking. There is a strong need to study the effects of socioeconomic factors on grassland degradation on the QTP region.

Currently, grassland degradation and its influencing factors are more studied at large scales and less studied at small scales(Chen et al., 2014; Gao et al., 2013). Because the study of grassland at large scale is macroscopic, the changes of grassland degradation and its influencing factors are manifested as universality and commonality. However, the grassland change characteristics and influencing factors are also be different due to the local unique topography, social development and grazing level, even if the grasslands in adjacent areas under the same pastoral. But, the characteristics of grassland changes at small scales and its influencing factors are often neglected. For example, different policy formulation and economic development orientation in different regions, leading to different degrees of development of animal husbandry, and thus different degrees of grassland degradation or restoration(Fayiah et al., 2020). At the same time, the different number of local households, the ratio of men and women, and the different distribution of family labor force will also affect their grazing and affect the quality of grassland. In addition, the levels of education determine people's understanding of grassland protection. However, the researches on the levels of number of local households, the ratio of men and women, the distribution of family labor force and education on grassland degradation were almost forgotten by researchers. Therefore, the local education levels were also considered when discussing the influencing factors of grassland degradation in this study. The grasslands in Maqu county (MQ), Xiahe County (XH) and Luqu County (LQ) are connected. The climate conditions in the 3 counties are slightly different, but the level of economic development is quite different. Are the grassland degradation characteristics in the 3 counties similar? What are the factors affecting their grassland degradation if the grassland change characteristics of the 3 counties are not consistent? So, this study taken 3 adjacent areas (MQ, XH and LQ) in the east of the QTP as the research object. Firstly, the changes of the total grassland area, ecosystem vulnerability and productivity in these regions were studied . Secondly, the factors affected the characteristics of grassland changes were discussed through climate factors (temperature, precipitation and water use efficiency) and socioeconomic factors (livestock, population, household, GDP and education) (**Figure 1**). Finally, corresponding rationally suggestions were put forward for each local government (**Figure 2**). The paper should also prove to be a useful reference for the maintenance of grassland ecosystem stability, and lay a foundation for formulating rational grassland management systems in the future.

Data and Methods

Study region

This study area included 3 adjacent grasslands in MQ, XH and LQ, respectively. They are located in Gannan Tibetan Autonomous Prefecture in southwestern Gansu Province, China **(Figure 3)**. They are located in the transition area between the northeastern edge of the QTP and the western part of the Loess Plateau (100°45'–103°25'E, 33°06'–35°34'N). The areas are composed of vast grasslands and are typical pastoral areas of the QTP. The average altitude in the study areas is 3600–3800 m, with the highest average altitude in MQ, followed by XH, and then the lowest in LQ. The trends of changes in the average annual temperatures are consistent with those of the average altitudes: MQ is the highest (5.07℃), followed by XH (2.93℃), and then LQ (2.76℃). The trends of changes in the average annual precipitations are consistent with those of latitudes: MQ is the highest (602.53 mm), followed by LQ (592.74 mm), and then XH (536.78 mm). In addition, the GDP of the 3 areas, from largest to smallest, is XH, MQ and then LQ; while the GDP per capita, again from largest to smallest, is MQ, LQ and then XH.

The study is composed of the aforementioned 3 counties – XH, LQ and MQ, from north to south. The areas of MQ and LQ are 10678 hm^2 and 4817 km^2, respectively. The area of XH changed in 1996, when the Ministry of Civil Affairs approved the establishment of a Hezuo city, and Hezuo town and seven townships were separated from XH. Following this adjustment, the total area of XH became 6959 km^2. The grassland areas in MQ and LQ comprise a large proportion of the total area, accounting for 73.00% and 73.87%, respectively. In XH, meanwhile, the grassland area makes up a relatively small proportion of the total area (63.22%). However, the trends in the proportion of cultivated land to the total area, and the proportion of forest land to the total area, are opposite to the trend in the proportion of grassland to the total area. The proportion of cultivated land to the total area in MQ, LQ and XH is 0.01%, 0.51% and 4.42%, respectively, and the proportion of forest land to the total area is 8.00%, 22.01% and 29.95%, respectively. There are 7 types of grassland in MQ (e.g., alpine meadow, marsh meadow, etc.), among which alpine meadow is the major one, with a wide distribution and large area. Alpine meadow and marsh meadow constitute the main grassland types in XH. There are again 7 grassland types in LQ, including alpine meadow, marsh meadow and shrub meadow, among which alpine meadow is the main type.

Data collection

The data used in this study include remote sensing, land type, topographic, meteorological and socioeconomic data from 1980 to 2018. Specifically, we used visual interpretation of 30-m-resolution Landsat image data of areas of land types and ecosystem vulnerability levels of grassland in the study region. The land-cover data were created mainly based on visual interpretation of Landsat Thematic Mapper images in vector format with a scale of 1:100000, and the average interpretation accuracy was 92.9% (Liu et al., 2003). The data were resampled to a spatial resolution of 500 m. The remote sensing data, which crucially for this study included the Normalized Difference Vegetation Index (NDVI). The data of NDVI were obtained from MODIS (the Moderate Resolution Imaging Spectroradiometer). All data were processed using ARCGIS 10.2 software. First, all data were projected into the same coordinate system (WGS 1984 UTM 45N), and then they were cut into the same spatial boundary according to the study area. Finally, the spatial resolution of the data was unified to 1 km by bilinear interpolation. The NDVI dataset comprises monthly data with 12 periods per year, and the annual NDVI was generated by selecting the annual maximum.

Net primary productivity (NPP) is a fundamental indicator of vegetation productivity that can reflect vegetation dynamics and the status of ecological processes. To identify the impacts of climate change and human activities on grassland change, three kinds of NPP are defined. Actual NPP (ANPP), indicated the actual situation in which grassland productivity was affected by both climate and human activities. It is calculated by using the Carnegie-Ames-Stanford Approach (CASA) model. The CASA model is a light use efficiency model that uses remote sensing data, meteorological data and vegetation types as the input parameters (Potter et al., 1993). Potential

NPP (PNPP) indicated the hypothetical situation in which grassland productivity was affected by climate, which is calculated from the Thornthwaite Memorial model. Human-induced NPP (HNPP) hypothesized that lost NPP was affected by human activities (Li et al., 2016). The calculation methods of ANPP, PNPP and HNPP all referred to Li et al (2016).

The meteorological data were derived from "http://cdc.nmic.cn/home.do" (China's Meteorological Data Sharing Service System), which includes the annual average temperature, annual average precipitation, and total solar radiation in the study area.

The number of livestock slaughtered, the number of stocks, and the commodity rate were obtained from the Third, Fourth, Fifth, Sixth, Seventh National Census in China.

Data on GDP, primary industry, secondary industry and tertiary industry, population, included households, number of men/women and number of villages/towns, education level were obtained from the "Gannan Yearbook".

Calculation of NPP

NPP is a fundamental indicator of vegetation productivity that can reflect vegetation dynamics and the status of ecological processes. To identify the impacts of climate change and human activities on grassland change, three kinds of NPP are defined. Actual NPP (ANPP), which is calculated by using the Carnegie-Ames-Stanford Approach (CASA) model. The CASA model is a light use efficiency model that uses remote sensing data, meteorological data and vegetation types as the input parameters (Potter et al., 1993). It has the characteristics of few data parameters and simple calculation. ANPP indicated the actual situation in which grassland productivity was affected by both climate and human activities. And potential NPP (PNPP) indicated the hypothetical situation in which grassland productivity was affected by climate, which is calculated from the Thornthwaite Memorial model. Human-induced NPP (HNPP) hypothesized that lost NPP was affected by human activities.

ANPP is determined based on the absorbed photosynthetically active radiation (APAR) and light-use efficiency (ε):

$$\mathrm{ANPP}(x, t) = \mathrm{APAR}(x, t) \times \varepsilon, \quad (1)$$

where APAR is the incident photosynthetically active radiation (PAR, $\mathrm{MJ \cdot m^{-2}}$). "x" is the spatial location and "t" is the time. absorbed by the vegetation per unit time, and "ε" is the actual light-use efficiency ($\mathrm{g \cdot C \cdot MJ^{-1}}$). APAR is calculated from the fraction of the total solar radiation (SOL, $\mathrm{MJ \cdot m^{-2}}$) accounted for by PAR (FPAR):

$$\mathrm{APAR}(x, t) = \mathrm{SOL}(x, t) \times \mathrm{FPAR}(x, t) \times 0.5, \quad (2)$$

where "0.5" is the proportion of SOL intercepted by the vegetation. Under ideal conditions, the vegetation can achieve its maximum light-use efficiency (ε_{max}), but in reality, this efficiency is constrained by both the temperature and the soil moisture (Xiao et al., 2022) . FPAR can be calculated from the "NDVI". These constraints are accounted for as follows:

$$FPAR_{(x,t)} = \frac{[NDVI_{(x,t)} - NDVI_{i,\min}] - (FPAR_{\max} - FPAR_{\min})}{NDVI_{i,\max} - NDVI_{i,\min}}, \quad (3)$$

where $\mathrm{NDVI}_{i,\max}$ and $\mathrm{NDVI}_{i,\min}$ are the minimum and maximum values of vegetation NDVI, respectively. The values of $\mathrm{FPAR}_{\max}$ and $\mathrm{FPAR}_{\min}$ are independent of the vegetation type, and are 0.001 and 0.95, respectively; and "ε" is accounted for by

$$\varepsilon(x, t) = T_{\varepsilon1}(x, t) \times T_{\varepsilon2}(x, t) \times W_{\varepsilon} \times (x, t) \times \varepsilon_{\max}, \quad (4)$$

in which "$T_{\varepsilon1}$" and "$T_{\varepsilon2}$" are the temperature stress coefficients for light-use efficiency, "W_{ε}" is the moisture stress coefficient, and "$\varepsilon_{\max}$" is the maximum light-use efficiency under ideal conditions. Yu et al. (2021) used remote sensing, meteorological, and measured "NPP" data to simulate the maximum light energy utilization rate of typical vegetation in China, where grassland is 0.542 g C·MJ^{-1}.

The Thornthwaite Memorial model was established based on the data used in the Miami model, but was modified to include Thornthwaite's potential evaporation model (Lieth et al., 1972). We used the Thornthwaite Memorial model to estimate PNPP (g C m^{-2} yr^{-1}):

$$\mathrm{PNPP} = 3000[1 - e^{-0.0009695(v-20)}], \quad (5)$$

$$v = \frac{1.05\gamma}{\sqrt{1 + (1 + \frac{1.05\gamma}{L})^2}}, \quad (6)$$

$$L = 3000 + 25t + 0.05t^3, \quad (7)$$

In these equations, "t" is the time, υ is the annual average actual evaporation volume (mm), "L" is the annual average evaporation volume (mm), "γ" is the annual total precipitation volume (mm).

HNPP (g C·m^{-2}·yr^{-1}) is the difference between PNPP and ANPP, and represents the loss or increment of NPP induced by human activities:

$$\mathrm{HNPP}\ (x, t) = \mathrm{PNPP}\ (x, t) - \mathrm{ANPP}\ (x, t). \quad (8)$$

Thus, a positive HNPP value represents an NPP loss induced by human activities and a negative value represents an NPP increment produced by human activities.

Calculation of RUE

The RUE ($g{\cdot}m^{-2}{\cdot}mm^{-1}$) is based on a simple regression:

$$\mathrm{RUE} = \frac{\mathrm{ANPP}}{P}, \quad (9)$$

where "P" is the annual average precipitation (mm).

Results

Spatiotemporal variations in land types and grassland NPP

From 1980 to 2018, the cultivated land areas in MQ, XH and LQ increased with time (**Table 1 and Figure 4**); the values in 2018 were 2.31, 1.23 and 2.05 times what they were in 1980, respectively. The forest areas in MQ and LQ have not changed obviously in the past 48 years, while the forest area in XH has significantly degraded (reduction of 3.82% compared with 1980). The areas of urban–rural residential land also expanded in these counties with time, among which MQ witnessed the largest change, followed by LQ and then XH; the values in 2018 were 3.51, 2.49 and 1.38 times what they were in 1980, respectively. The proportions of grassland area in MQ and XH were basically stable, maintaining at 73% and 63%, respectively, from 1980 to 2018. In LQ, the proportion of grassland was 72% in different periods, except in 2010 when it was 71%. From the perspective of area, the grassland in MQ also increased with time, by 41.56 km^2 in 2018 compared with 1980. The grassland area in XH changed slightly in different years. However, the grassland area in LQ decreased continually with time. By 2018, the grassland area in LQ had decreased by 42.23 km^2 compared with 1980.

The areas of high and medium coverage grasslands in MQ and LQ decreased continuously with time, while the areas of low coverage grassland in these counties increased (**Table 2 and Figure 5**). In 2000, the area of low coverage grassland in MQ was 1195.26 km^2, but in 2010 this was 1431.23 km^2 – an increase of 235.97 km^2 in those 10 years. In XH, the area of medium coverage grassland (except in 2010) decreased with time, while the area of low coverage increased. However, the areas of high coverage grassland increased from 1990 to 2000, and then declined after 2000. Among the three counties, the high, medium and low coverage grassland areas as a proportion of the total grassland area in MQ were 24.63%, 58.17% and 17.21%, respectively; whereas, the proportions in XH were 58.15%, 40.11% and 1.74%, and in LQ were 80.53%, 19.47% and 0.003%. The growth rate of low coverage grassland was largest in MQ, followed by XH and then LQ.

The trends of change in ANPP, PNPP and HNPP in XH, MQ and LQ were different in different years (**Figure 6**). However, from an overall point of view, the ANPP of the three counties showed a downward trend, and the ANPP of XH declined the most (44.58% lower in 2015 than in 1986). The PNPP of MQ and XH showed an upward trend, while the change in PNPP of LQ was flatter during different years. The HNPP in MQ showed an increasing trend, while in LQ it showed a decreasing trend, and in XH a smaller change between different years.

Spatiotemporal variations in climate changes

From 1980 to 2018, the annual average temperature in all three counties increased with time (**Figure 7**). The annual average temperature in XH, MQ and LQ increased by 0.03 °C·yr^{-1}, 0.025 °C·yr^{-1} and 0.013 °C·yr^{-1}, respectively. From 1980 to 1990, the annual average temperature in XH, MQ and LQ was 2.27℃, 5.21℃ and 3.2℃, respectively; while from 2010 to 2020, they were 3.48℃, 5.19℃ and 3.12℃. During 1980–2010, the annual average temperature of XH increased rapidly (0.48°C·10 yr^{-1}), but during 2010–2018 it increased relatively slowly (0.25°C·10 yr^{-1}). In MQ and LQ, the annual average temperature mainly increased between 1990 and 2010 (0.22°C·10 yr^{-1} and 0.73°C·10 yr^{-1}), whilst changing only slightly in other periods.

The annual average precipitation showed a rising trend in MQ and XH from 1980 to 2018 (**Figure 8**). Among them, the annual average precipitation in XH during 1990–2000 increased by 17.32 mm compared with 1980–1990, and during 2010–2018 increased by 39.40 mm compared with 2000–2010, whilst the changes were relatively small during other periods. In MQ, meanwhile, the annual average precipitation during 1990–2000 decreased by 52.7 mm compared to that during 1980–1990, and during 2000–2018 it increased by 74.6 mm compared to that during 1990–2000. In LQ, the annual average precipitation during 2010–2000 increased by 40.5 mm compared with that during 1990–2000, while during 1990–2000 compared with 1980–1990, and during 2018–2010 compared with 2000–2010, it decreased by 24 mm and 5.3 mm, respectively.

The RUE in the three counties showed an upward trend over time (**Figure 9**). In the four time periods of 1980–1990, 1990–2000, 2000–2010 and 2010–2018), the RUE in MQ was 0.67, 0.73, 0.94 and 0.92 g·m^{-2}·mm^{-1}, respectively; while in XH it was 0.82, 083, 1.16 and 1.04 g·m^{-2}·mm^{-1}, and in LQ it was 0.77, 0.84, 0.98 and 1.01 g·m^{-2}·mm^{-1}.

Spatiotemporal variations in socioeconomic factors

This study found that both the numbers of marking and the commodity rates of livestock in the three counties showed an increasing trend from 1980 to 2018 (**Figure 10**). The numbers of livestock marketing in XH, MQ and LQ increased rapidly from 2010 to 2018 – by 90%, 75% and 97% compared with those during 2000–2010, respectively. The numbers of livestock stock in

XH, MQ and LQ showed an upward trend from 1980 to 2008, and reached their peaks in 2008 (1018500, 1060000 and 729900 heads, respectively). After 2008, the numbers of livestock stock in the three counties showed a slow declining trend.

The GDP of MQ and LQ in 1980 was 15 million yuan and 11 million yuan, respectively, which rose to 1.586 billion yuan and 1.016 billion yuan in 2018 – growth multiples of 105.73 and 92.36, respectively **(Figure 11)**. From 1980 to 1991, the growth rate of GDP in XH was relatively slow, from 28 million yuan to 89 million yuan; whereas from 1991 to 2018 it was faster, from 89 million yuan to 1.660 billion yuan. At the same time, the proportion of primary industry output in XH, MQ and LQ gradually decreased, while tertiary industry output gradually increased. After 2003, the percentage of primary industry output in XH and LQ was lower than 50%, and in MQ it was lower than 50% in 1996. From 1980 to 2018, the GDP per capita also increased continually in the three counties; it increased rapidly in MQ after 1995, and in XH and LQ after 2005. Compared with 1980, the GDP per capita in XH, MQ and LQ had increased by 72, 45 and 51 times in 2018, respectively.

From 1980 to 2018, the population, population density, number of households, and household density in MQ and LQ showed an upward trend **(Figure 12)**. Compared with 1980, the population of MQ and LQ in 2018 increased by 132.8% and 71.7%, respectively; whilst at the same time, the number of households increased by 231.4% and 108.5%. The change in the population of XH was a special circumstance because the state approved the establishment of Hezuo city in 1996, which involved one town and seven counties originally belonging to XH being divided into the jurisdiction of Hezuo city, and therefore the population of XH showed a rapid decline in 1997. However, the population and population density still increased from 1980 to 1997, and then continued to increase from its new (lower) level in 1997 to 2018. XH, MQ and LQ all showed higher numbers of men than women **(Figure 13)**. However, the urban populations of the three counties were significantly smaller than their rural populations in 1990, 2000 and 2010; although, the changes in the urban–rural populations of MQ and LQ were similar in 2018.

The proportion of the population that were educated increased with time in MQ and LQ **(Figure 14)**; whereas, in XH, the proportion increased from 2000 to 2010, and then decreased slightly after 2010. At the same time, the proportion of the population with a college education in the three counties increased.

Correlation analysis

Through correlation analysis (**Tables 3**), the high coverage grassland and cultivated land area in MQ had extremely significant negative correlation, while them in XH had extremely significant positive correlation ($P < 0.01$). In LQ, grassland area had extremely significant negative correlation with low grassland area; while it had extremely significant positive correlation with high grassland area ($P < 0.01$).

The grassland area had extremely significant positive correlation with numbers of livestock marketing, commodity rate, GDP, primary industry, tertiary industry, household density, junior middle school education, university education in MQ ($P < 0.01$) (**Figure 15**). HNPP and high coverage grassland had extremely significant negative correlation; HNPP and high coverage grassland had opposite performance ($P < 0.01$). In XH, the grassland area had extremely significant negative correlation with primary school education ($P < 0.01$). Rural and medium coverage grassland had extremely significant positive correlation ($P < 0.01$). In LQ, The grassland area and high coverage grassland showed extremely significant positive correlation, while that and medium coverage grassland/numbers of livestock stock/secondary industry/primary school education showed extremely significant negative correlation ($P < 0.01$). At the same time, temperature and medium coverage grassland had extremely significant negative correlation ($P < 0.01$).

Discussion

Change characteristics of grassland degradation in adjacent areas

Grassland degradation has become an emerging topic in the fields of grassland management and environmental protection (Manssour et al., 2011). The 3 areas in this study had different change characteristics in grassland area and grassland productivity from 1980 to 2018. In the past 38 years, the total grassland area in Maqu County had increased by 0.53% (1.16 hm^2); that in Luqu County had decreased by 1.24% (43.23 hm^2); while that in Xiahe County did not change significantly. This indicated that in the 3 adjacent areas of Gannan Prefecture, the grassland areas were quite different. Therefore, it was necessary to analyze the grassland characteristics of the 3 areas separately. In the study, grassland ecosystem vulnerability was divided into 3 levels, namely high, medium and low coverage grassland. In Maqu County, the low coverage grassland area showed an increasing trend, while the areas of the high medium coverage grasslands showed decreasing trends. Meanwhile, high coverage grassland showed significant positive correlation with medium coverage grassland, while both them showed significant negative correlation with low coverage grassland. Therefore, it could be judged that the higher coverage grassland flowed to the lower coverage grassland in Maqu County. It indicated that the grassland ecosystem in Maqu County became more vulnerable. The study also found that the high coverage grassland and the medium coverage grassland areas decreased by 209.39 hm^2 altogether, while the low coverage grassland area increased by 250.55 hm^2. Therefore, it could be judged that in addition to the flow of high and medium coverage grassland to low coverage grassland, other land had also changed to low coverage grassland. In Xiahe County, high coverage grassland area increased by 53.78 hm^2, while medium coverage grassland area decreased by 54.763 hm^2, and low coverage grassland area changed less. At the same time, high coverage grassland and medium coverage grassland had extremely significant negative correlation, indicating that a part of medium coverage grassland was transformed to high coverage grassland in Xiahe County. In Luqu County, there were only high and medium coverage grasslands in the years 1980-2000, while low coverage grassland began to appear after 2000. In the past 38 years, the area of high coverage grassland area decreased significantly, while the medium and low coverage grassland areas changed less. The total grassland degradation area was 43.23 hm^2, while the high coverage grassland area was reduced by 41.18 hm^2 in Luqu County. Meanwhile, the total grassland area and the high coverage grassland area had extremely significant positive correlation, which showed that the grassland degradation was mainly caused by the decreased high coverage grassland.

As the core issue of grassland degradation, the reduction of NPP had become the focus of research on ecosystem change (Wessels et al., 2007). There are also coupled effects on the production of grassland ecosystem, i.e., NPP is affected by both climate changes and human activities (He et al., 2016). Methods that compare the ANPP and PNPP of vegetation can determine the impact of humans on vegetation productivity (Li et al., 2016). ANPP represents the actual situation of vegetation productivity, which is influenced by both climate and human activities, while PNPP refers to the potential for plant growth in the absence of human disturbance and is only affected by climate changes (Xu et al., 2010) . The difference between PNPP and ANPP is used to measure the HNPP. In the study, ANPP of 3 grassland areas were decreased gradually with time, and the ANPP of grassland fell the most in Maqu County, followed by Luqu County, while Xiahe County did not drop significantly. This also showed that the worst degradation of grassland quality in Maqu County, while that in Xiahe County was not obvious. PNPP showed an upward trend with time in Maqu County and Xiahe County, indicating that the influence of climate on plant growth potential in Maqu County and Xiahe County was increasing. In our study, PNPP showed the same trend as temperature and precipitation, while ANPP showed an opposite trend. This difference was due to the different geographical locations as well as differences in climate. Several scientists believe that human activity is the dominant factor affecting the degradation of the QTP's grasslands (Pan et al., 2017) . HNPP showed an increasing trend in Maqu County and Xiahe County, indicating that the impact of human activities on grassland vegetation productivity is increasing. In Luqu County, PNPP showed an increasing trend, while HNPP showed a decreasing trend, indicating that the impact of human activities was relatively less than that of climate changes on grassland productivity in Maqu

County. The driving forces behind changes in grassland can be quantitatively evaluated, through PNPP and HNPP, and the impacts of climate change and socioeconomic factors on these changes can be accurately identified (Yuan et al., 2021). In general, the total grassland area was increased, but the grassland quality was significantly reduced, and other land types were converted to low coverage grassland in Maqu County. The total grassland area was increased, but the grassland quality was degraded slightly in Xiahe County. The total grassland area and quality were all degraded in Luqu County.

Influencing factors of grassland degradation in adjacent areas

Influencing factors of grassland degradation in Maqu, Xiahe, and Luqu counties were different. Climate changes and human activities are not independent, with many coupled relationships existing between them (Xiong et al., 2019). Human activities have an important influence on the changes in land use on the QTP. In addition to animal husbandry and agriculture, changes in lifestyle brought by urbanization, economic growth patterns, tourism and industrial activities are new factors also can influence the grassland change (Chuvieco et al., 2014). In Maqu County, there were many factors affected the total grassland area, for example GDP and the primary industry (mainly for animal husbandry) and the tertiary industry had a extremely significant impact on total grassland area. With the increased GDP, people's demand for quality of life had also increased. When the disturbance intensity of socioeconomic factors exceeds the carrying capacity of the ecosystem, resulting in increased ecosystem vulnerability, the grassland will become degraded (Guo et al., 2016) . Overgrazing is also one of the main causes of grassland degradation on the QTP (Liu et al., 2018). In the study, the temperature and precipitation also had the impact on the total grassland area in Maqu County. It showed that the increase of the total grassland area was also increased due to the warm and wetting of the climate. Sufficient rainfall promoted the growth of grassland plants, meaning the grassland area increased (Eze et al., 2018) . Chen et al. (2014) also found that rising temperature and precipitation were promoted improvements in expansion of the grassland area. So, when carrying out grassland restoration, it is not only necessary to combine the characteristics of the grassland ecosystem itself, but also to consider the impacts of climate changes (Jiang et al., 2016). The study also found that HNPP was negatively correlated with high and medium coverage grasslands, but HNPP was positively correlated with low coverage grassland; ANPP showed the opposite to HNPP. This showed that socioeconomic factors rather than climate changes was the main cause of grass changes on the QTP region (Zhang et al., 2015). The increased cultivated land means the increased damage of grassland, woodland and wetland. A similar phenomenon was observed in this study, that is, cultivated land had a negative impact on high coverage and medium coverage grasslands, and a positive impact on low coverage grassland. This also showed that the cultivated land indirectly driven the grassland degradation. Chen et al., (2015a) also found that human activities, such as excessive grass reclamation would have a great impact on the ecological environment. The future protection of ecosystems should not ignore human interference, and sustainable human activity is a factor to be considered in ecological restoration. An interesting phenomenon was also found in the study, the higher the education level of local residents, the more favorable the increase of total grassland area and high/medium coverage grassland area. The improvement of education level means that people have a clearer understanding of ecological environment damage, grassland degradation and other hazards, but also can improve people's rationality of grassland use, and thus reduce the degradation of grassland. In Maqu County, the part of the total and low coverage grassland areas were converted from other lands. The conversion of other lands into grassland did not mean the benign development of ecology, but might be because social development and climate change had destroyed the existing environment of other lands, and then transformed into the grassland. For example, the development of society promoted the increase of the demand for water, and the unreasonable water use caused the reduction of the water area, and same water area became the grassland (the water area had decreased by 6% during the 38 years). The total grassland area showed a significant negative correlation with the unutilized land, and the unutilized land was decreased by 79.84 hm2 in 38 years. So it could be speculated that a part of the unutilized land was converted into the grassland. This might be due to the rising temperature （0. 96℃ during 38 years), caused the snow area to melt, turned the snow into grassland, etc. Also found in other studies, the increases in temperature promoted the increases in the grassland area, which may have been due to the reduction in snow cover on the land with the increased temperature, causing conversion of the previously snow-covered land into grassland (Chen et al., 2015b) . Sun et al. (2015) also thought that great changed in vegetation due to climate warming was found in the northwestern Loess Plateau.

In Xiahe County, high coverage grassland and cultivated land had extremely significant positive correlation. High grassland area had extremely significant negative correlation with forest and middle coverage grassland. These phenomena illustrated that the decrease of forest and intermediate coverage grassland area and the increase of high coverage grassland area was due to the increase of cultivated land. This might be due to the increase of cultivated land (61.624 hm^2 during 38 years) forced the forest reduction (81.54 hm^2 during 38 years) , and the reduced forest turned to cultivated land or high coverage grassland. The continuous increase in arable land is mainly due to the continuous increase in the population and number of households, and the growth of the economy and livestock numbers have also forced herds to develop more grasslands (Gao et al., 2016). At the same time, herdsmen also urgently need to expand the area of cultivated land for the planting pasture to improve the pasture utilization rate. Studies had shown that the utilization rate of artificially planted pasture was three to four times that of natural pasture (Diabate et al., 2018) . Therefore, the main reasons for the continuous increased cultivated land and urban–rural residential land areas are the continuous increased population and households, as well as the continuous economic growth and livestock numbers, all of which had forced herders to exploit more cultivated land to meet their living needs. In the study, the unutilized land and low coverage grassland had extremely significant positive correlation, so it could be speculated that a part of the unutilized land was converted to the low coverage grassland. Xiahe County launched “The National Project of Returning Farmland to Forest (Grass)” in 1997, which led to a certain level of grassland restoration in 2000. High grassland area had extremely significant negative correlation with livestock commodity rate, male number, female number. This was due to the increased numbers of male and female,and then that increased the demand for livestock products, so that increased the livestock commodity rate. The increased livestock commodity rate also caused the burden of grassland carrying capacity, and thus reduced the grassland quality. It was a strange phenomenon that the numbers of male and female had extremely significant effect with high coverage grassland, while the population number had no significant effect with high coverage grassland. This was due to the population members had greatly changed as the changes about administrative divisions in Xiahe County in 1997 (Hezuo city was established in 2000). Therefore, population number was not closely related to the grassland area or quality. The study also found that the improved education level could effectively promote the increase of grassland area, while improved conversion of the medium and low coverage grasslands to the high coverage grassland. This phenomena was due to the improvement of education level, which increased people's protection of grassland, and then improved the grassland area and productivity.

In Luqu County, the total grassland area and high coverage grassland area decreased, while the medium and low coverage grasslands changed slight. At the same time, water area had significant negative correlation with total grassland and high coverage grassland. This indicated that the total grassland and high coverage grassland areas might be caused by the increased water area that occupied the original high coverage grassland area. Also, as cities invade grasslands, their impervious surfaces change the reflectance and groundwater flow in cities, and artificial structures break the original grassland landscape into fragments, consequently causing loss of high coverage grassland habitat. The study also found that the number of livestock stock had a significant impact on the grassland area and quality, which was also the main cause of the grassland degradation in Luqu County. In order to meet the demand of population and living standard growth for livestock products, the number of livestock and the area of cultivated land had also increased, which had caused the grassland areas were distributed mostly, and imposing much pressure on the grassland's fragile ecological environment (Lin et al., 2020). From our research, it could be seen that the numbers of livestock stocking and marketing had increased significantly in 2018 compared with those in 1980. This exacerbated the carrying capacity of grasslands for livestock, leaded to grassland degradation. At the same time, in 2008 and 2009, the livestock stocking numbers reached a peak, and these high numbers would inevitably have caused pressure on grassland grazing, thereby reducing the area of grassland and its ratio to total area. The research showed that the secondary industry had a extremely significant negative impact on the grassland area and quality, that is, the development of industry accelerated the degradation of grassland in Luqu County. This was due to the increased CO_2 emissions caused by the growth of secondary industry. The increased CO_2 concentration had led to increased temperatures, which in turn had caused a reduction in high coverage grassland, resulting in grassland degradation. In general, the growth of secondary industry led to increased temperatures, which indirectly affects grassland degradation (the transformation of high-coverage grassland into medium- and low-coverage grasslands). Gong et al. (2017) also found that secondary industry had accelerated grassland degradation. With the development of society, more and more people had changed from residing in rural areas where they made their living from grazing animals, to lived in urban areas where they found employment from the development of secondary industry, which led to increased CO_2 emissions and rising temperatures (Yuan et al., 2021) . Compared with Maqu County and Xiahe County, the impact of temperature on the grassland degradation in Luqu County was more obvious. The increased temperature significantly reduced the total and medium coverage grassland areas, while increased the low coverage grassland area. Other scientists believed that drought had exacerbated the degradation of the QTP's grasslands, because warming increased evaporation, which was not conducive to the growth of grassland vegetation (Chen et al., 2015) . An increase in temperature caused the permafrost to thaw, the water from which seeped out and the soil surface became dry, which was not conducive to vegetation growth (You et al., 2017). Moreover, warming increased evaporation could reduce the average soil moisture in the growing season significantly (Fu et al., 2013) . So, the increase in temperature had changed the vulnerability of the grassland, and grassland areas with high coverage had gradually decreased, converted into grassland areas of medium and low coverage. Compared with Maqu County and Xiahe County, Luqu County has lower altitude, but the average temperature in Luqu County is lower than that in Maqu County and Xiahe County, which is due to the special terrain in Luqu County, so the grassland ecosystem in Luqu County is more sensitive to temperature changes. The response process of grassland to topography, climate change and human activities is a complex dynamic process. Different geomorphic conditions would lead to the spatial differences in temperatures and precipitation, which would make the obvious spatial differences of grassland in different areas (Zoungrana et al., 2018; Venkatesh et al., 2022). The education level also significantly affected the grassland area and quality, that is, the decrease of illiterates number could alleviate grassland degradation. In 3 study areas, education level had a significant effect on grassland degradation, however the relationship between education level and grassland degradation was unappreciated in previous studies.

Suggestions of grassland degradation in adjacent areas

Revegetation of degraded ecosystems is mainly attributed to the environmental protection policies (Naeem et al., 2021). To effectively restore the grassland, different suggestions should be given to the different characteristics of grassland degradation according to the different influencing factors in different areas. In Maqu County, it is recommended to reduce the cultivated land area, slow down the primary industry (numbers of livestock stock and market, commodity rate) and the third industry. In Xiahe County, it is recommended to reduce the commodity rate of livestock to improve the grassland quality. In Luqu County, it is suggested to reduce the number of livestock stock and slow down the secondary industry to improve the grassland area and quality. At the same time, in all the 3 areas, it need to improve the education level of local people, and then to improve people's awareness of ecological protection and the rational use of grassland.

Conclusions

In Maqu County, the grassland area was increased, but the grassland quality was decreased significantly. The main factors caused this phenomenon were cultivated land, primary industry, tertiary industry and education level. Therefore, it is suggested to reduce the local cultivated land area, slow down the development of the primary and tertiary industries, and improve the education level. In Xiahe County, the grassland degradation was not obvious. Improving the education level of the local people is conducive to the grassland restoration. In Luqu County, grassland area and quality had declined, which was due to the increase of livestock production, the increase of the secondary industry, illiteracy and temperature. Therefore, to control the development of local industry and the number of livestock stock, and to improve the educational literacy of the whole people can restore the grassland. This work provides a reference for the formulation of local policies on grassland protection and restoration and other related policies.

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Figure 1

Impacts of climate changes and socioeconomic factors on grassland degradation.

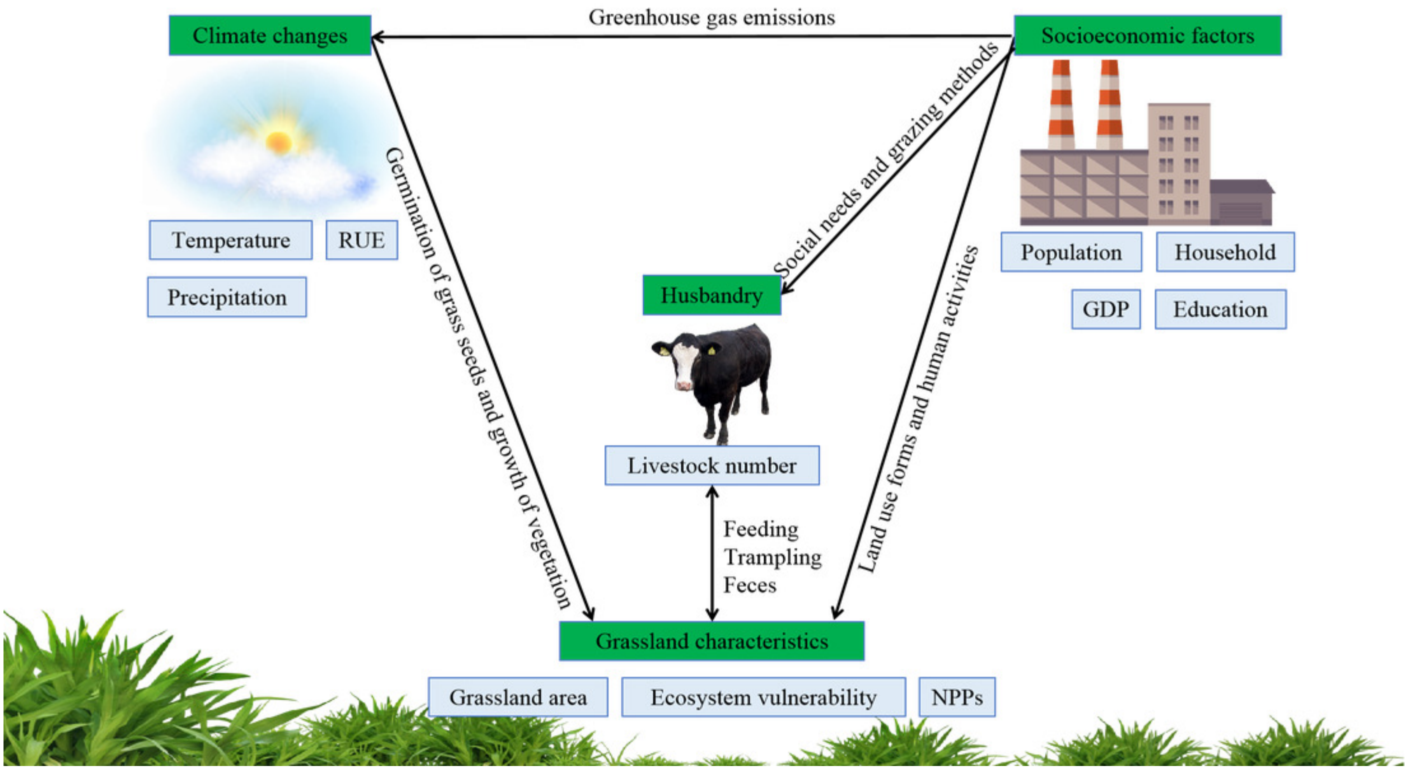


Figure 2

Scientific assumptions and research ideas.

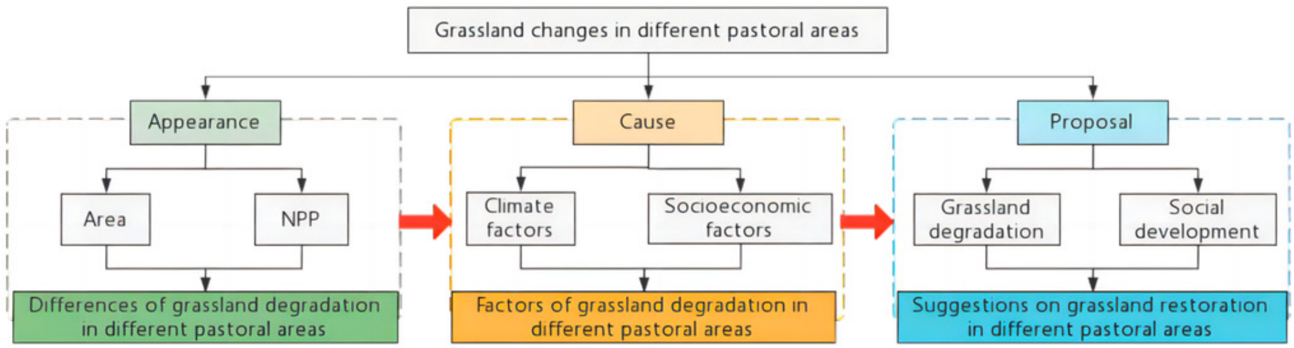


Figure 3

Geographical location of the study area.

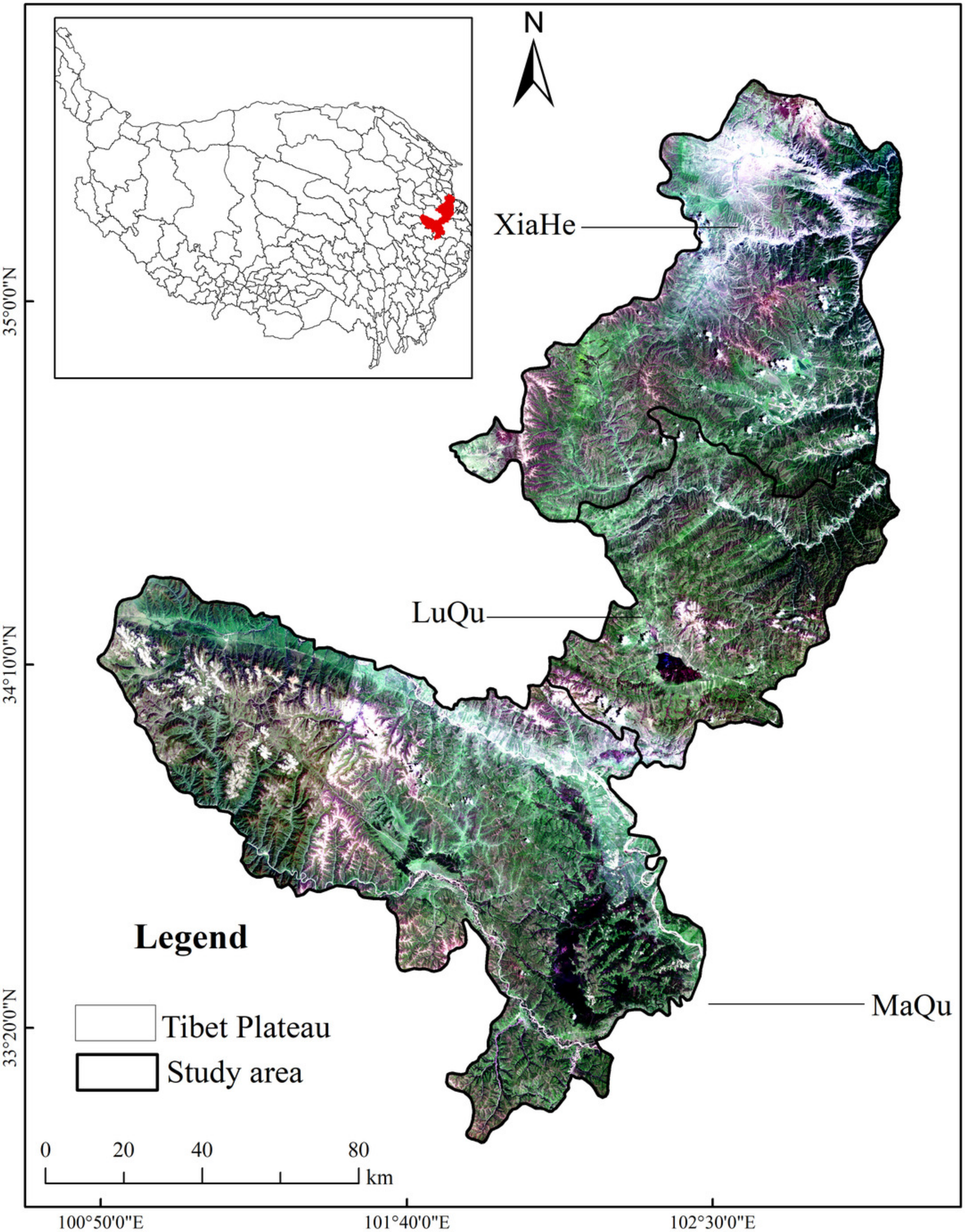

N
XiaHe
LuQu
MaQu
Legend
Tibet Plateau
Study area
0
20
40
80
km
35°0'0"N
34°10'0"N
33°20'0"N
100°50'0"E
101°40'0"E
102°30'0"E

Figure 4

Areas of different land cover classification in the counties of Maqu, Xiahe and Luqu (hm^2).

The pictures from top to bottom depict Maqu County, Xiahe County and Luqu County; and from left to right, represent the years 1980, 1990, 2000, 2010 and 2018.

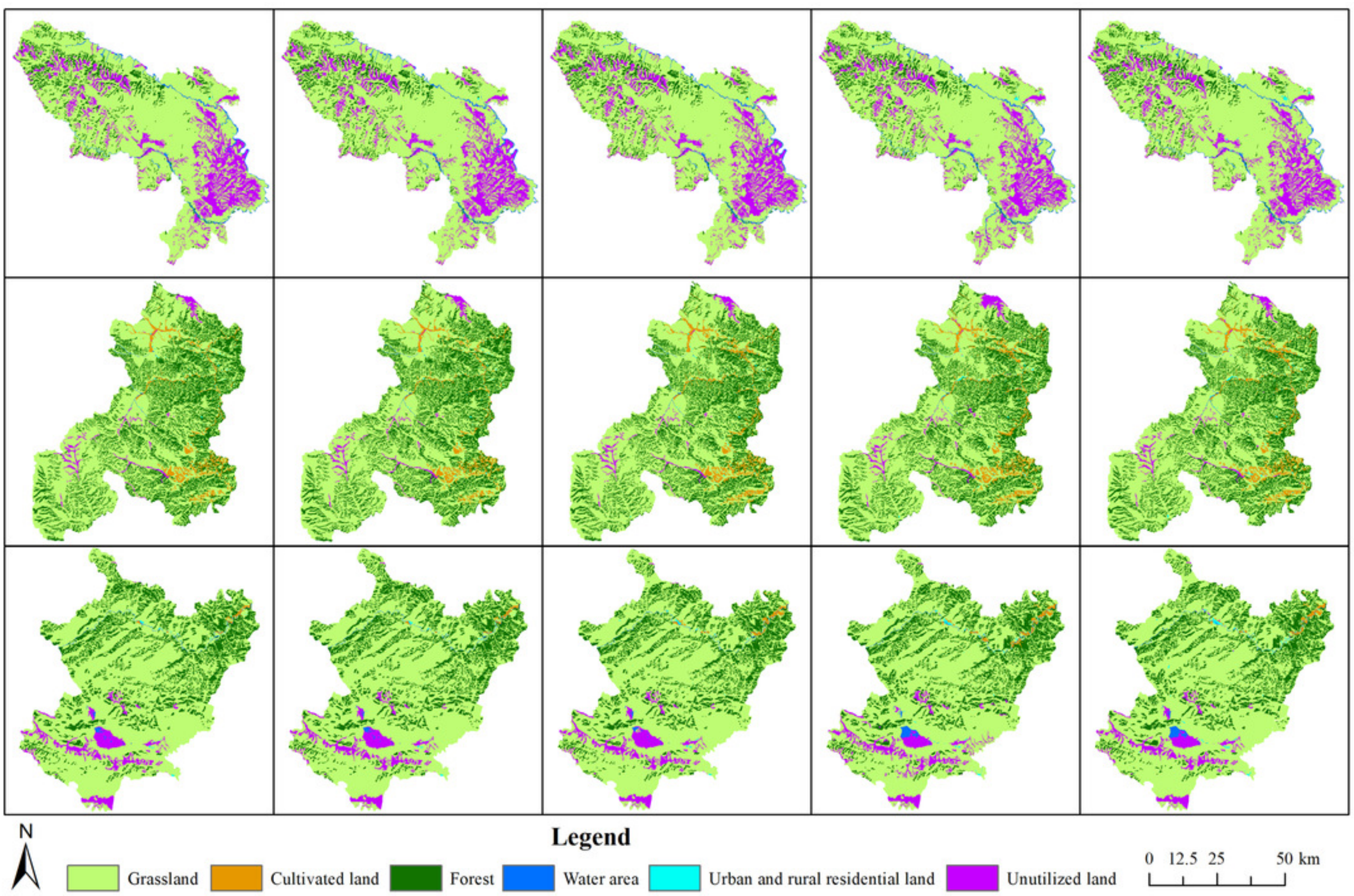


Figure 5

Changes in different ecosystem vulnerability levels of grassland in the counties of Maqu, Xiahe and Luqu

The pictures from top to bottom depict Maqu County, Xiahe County and Luqu County; and from left to right, they represent the years 1980, 1990, 2000.

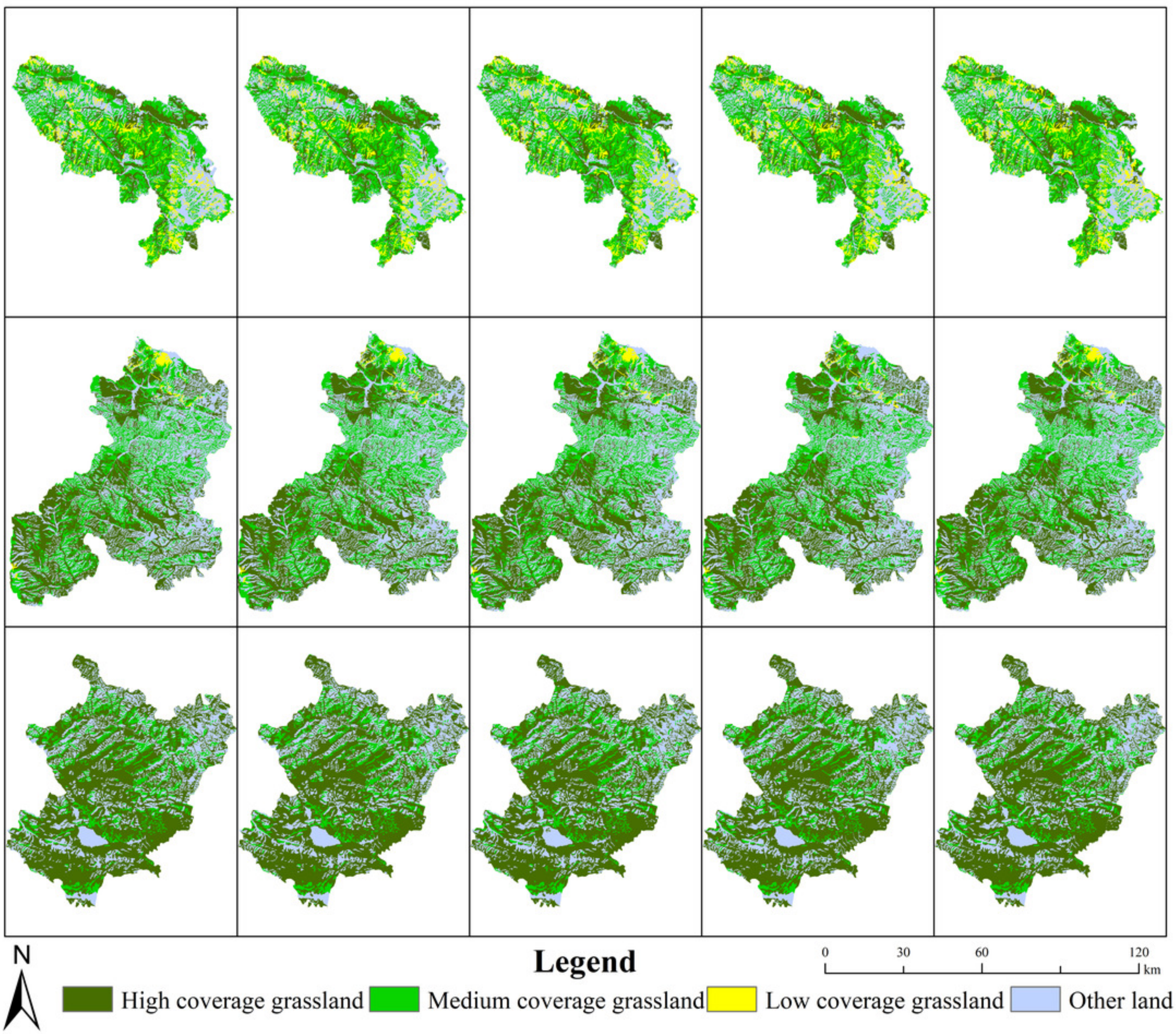
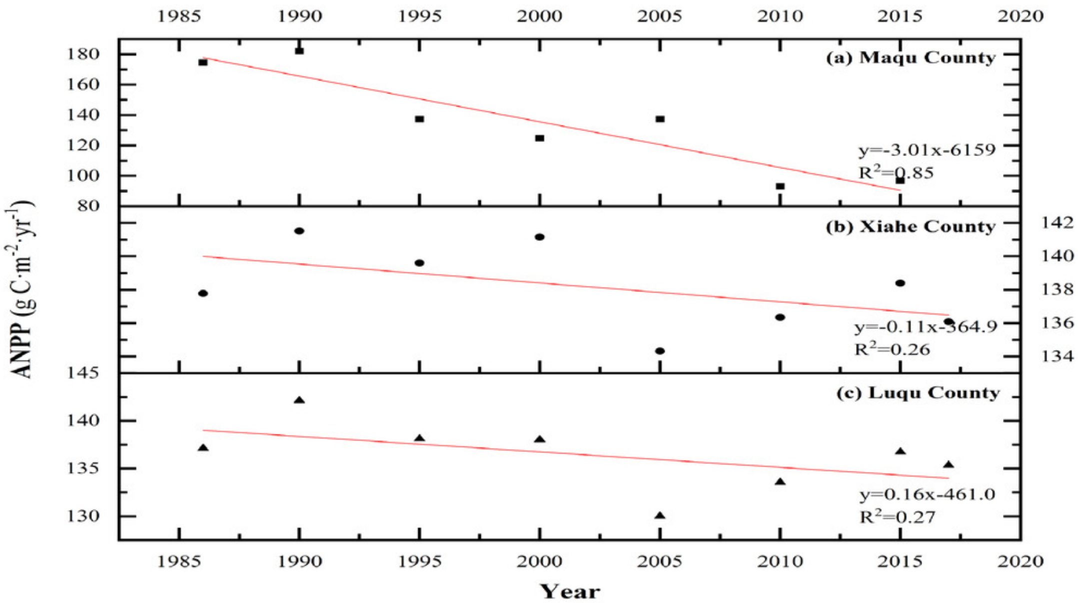
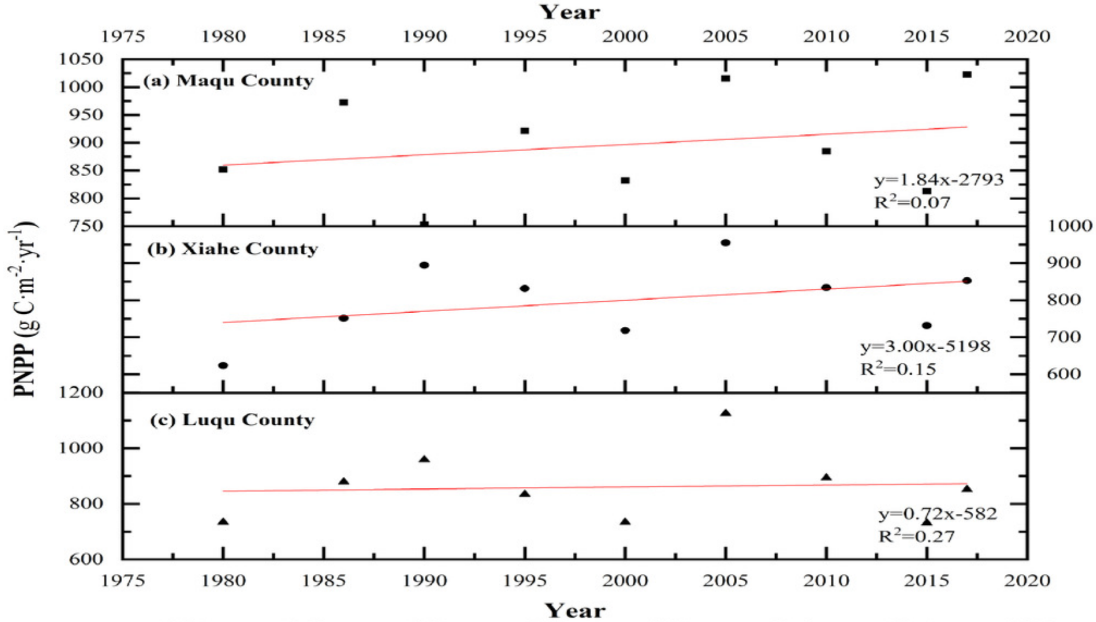


Figure 6

Changes in ANPP, PNPP, HNPP in the counties of Maqu, Luqu and Xiahe (g C·m^{-2}·yr^{-1}).


(a) Maqu County
y=-3.01x-6159
R^2=0.85
(b) Xiahe County
y=-0.11x-364.9
R^2=0.26
(c) Luqu County
y=0.16x-461.0
R^2=0.27
ANPP (g C·m^{-2}·yr^{-1})
Year


(a) Maqu County
y=1.84x-2793
R^2=0.07
(b) Xiahe County
y=3.00x-5198
R^2=0.15
(c) Luqu County
y=0.72x-582
R^2=0.27
PNPP (g C·m^{-2}·yr^{-1})
Year

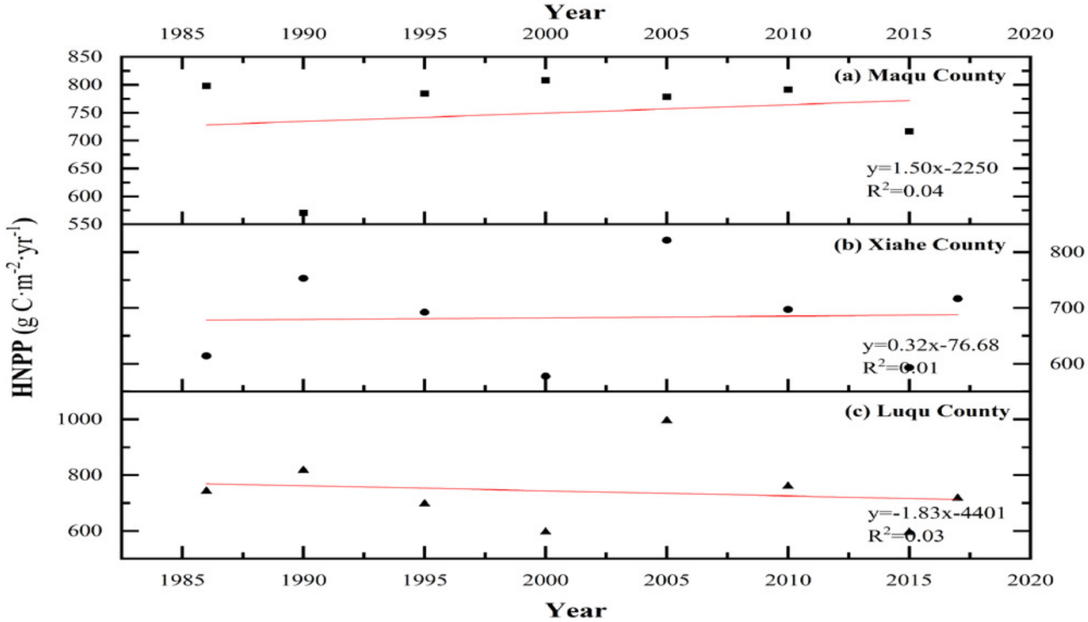

(a) Maqu County
y=1.50x-2250
R^2=0.04
(b) Xiahe County
y=0.32x-76.68
R^2=0.01
(c) Luqu County
y=-1.83x-4401
R^2=0.03
HNPP (g C·m^{-2}·yr^{-1})
Year

Figure 7

Changes in annual average temperature in the counties of Maqu, Luqu and Xiahe.

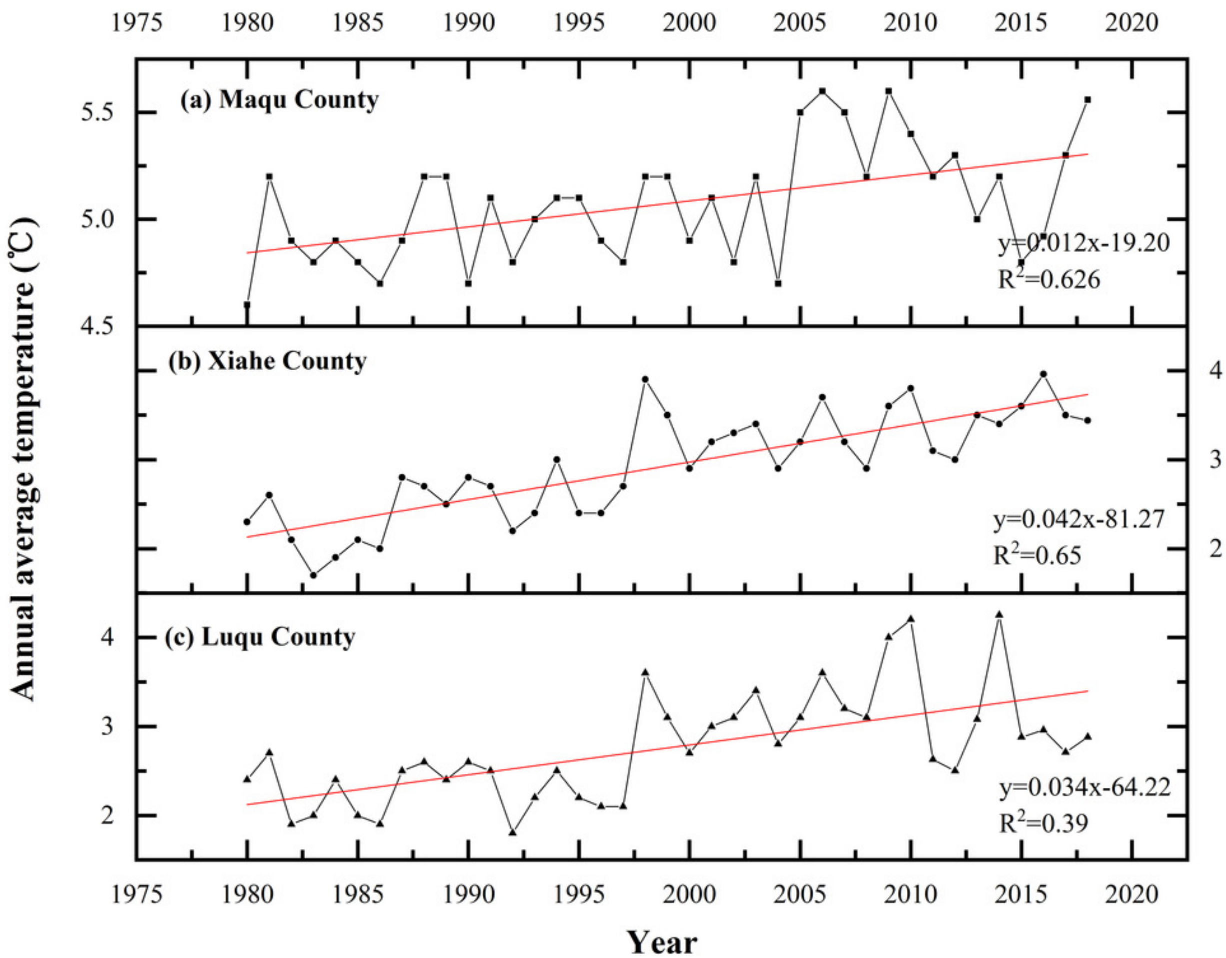


Figure 8

Changes in precipitation in the counties of Maqu, Luqu and Xiahe.

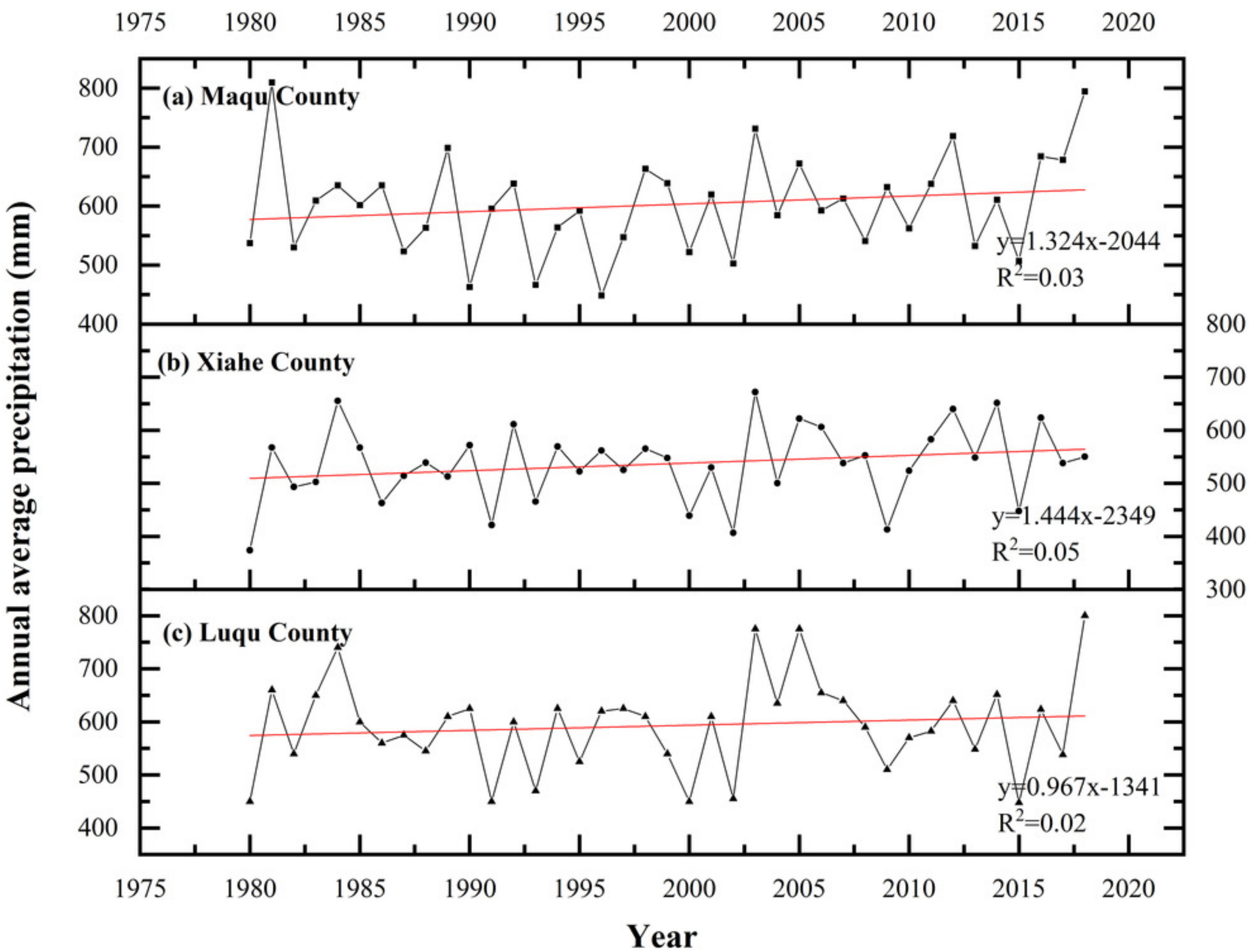


Figure 9

Changes in RUE in the counties of Maqu, Luqu and Xiahe.

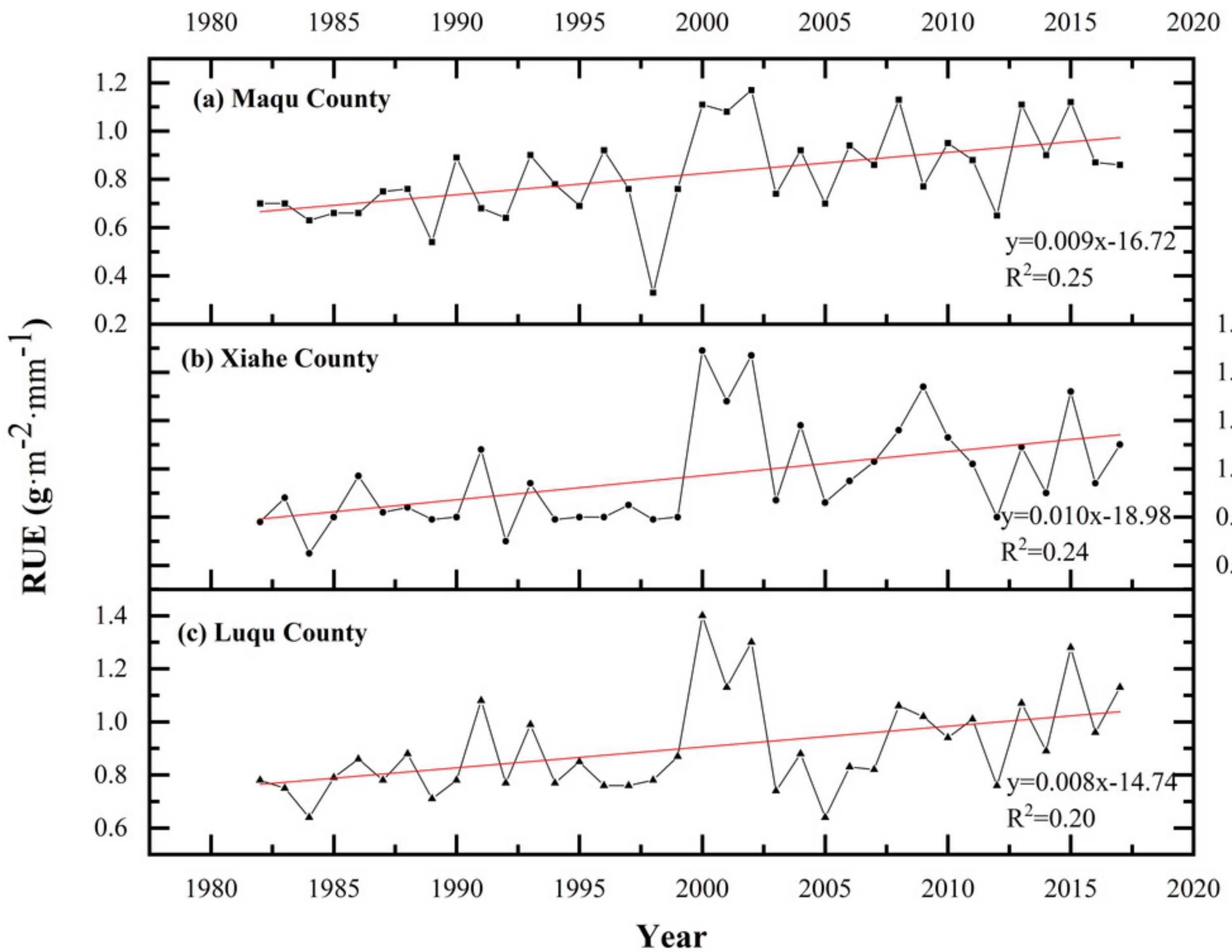


Figure 10

Changes in livestock numbers in the counties of Maqu, Luqu and Xiahe.

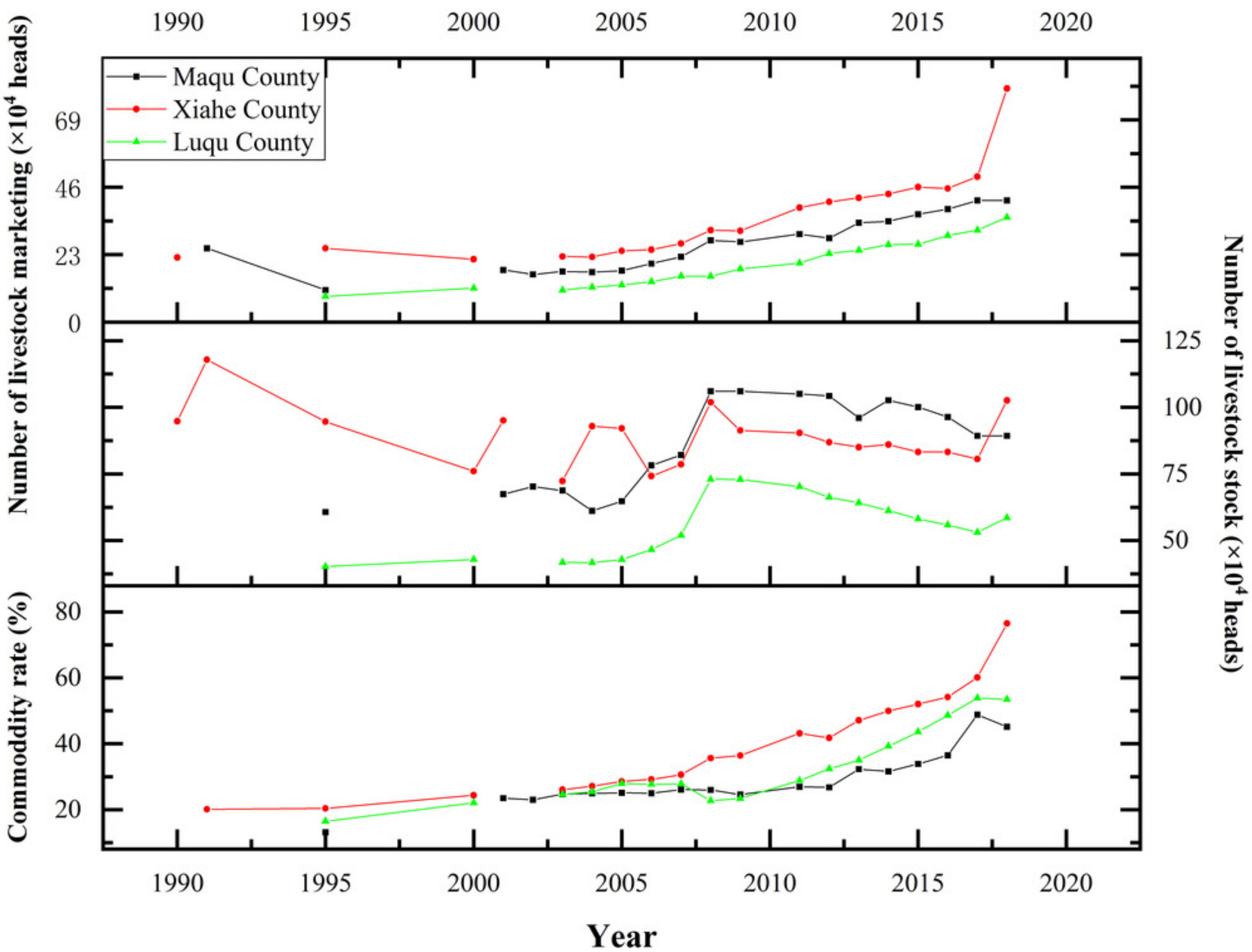


Figure 11

Changes in GDP and industrial output in the counties of Maqu, Luqu and Xiahe.

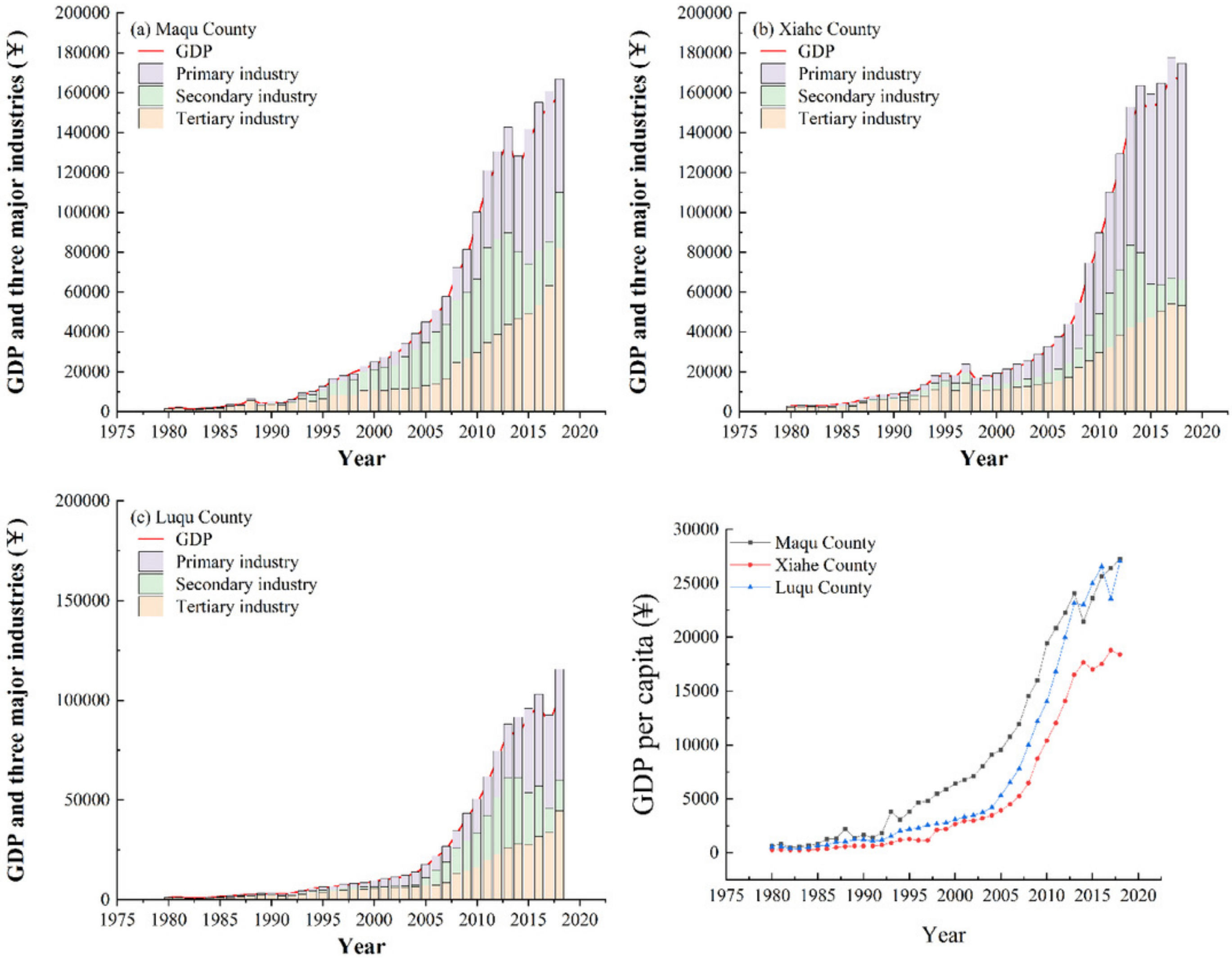


Figure 12

Changes in population and household in the counties of Maqu, Luqu and Xiahe.

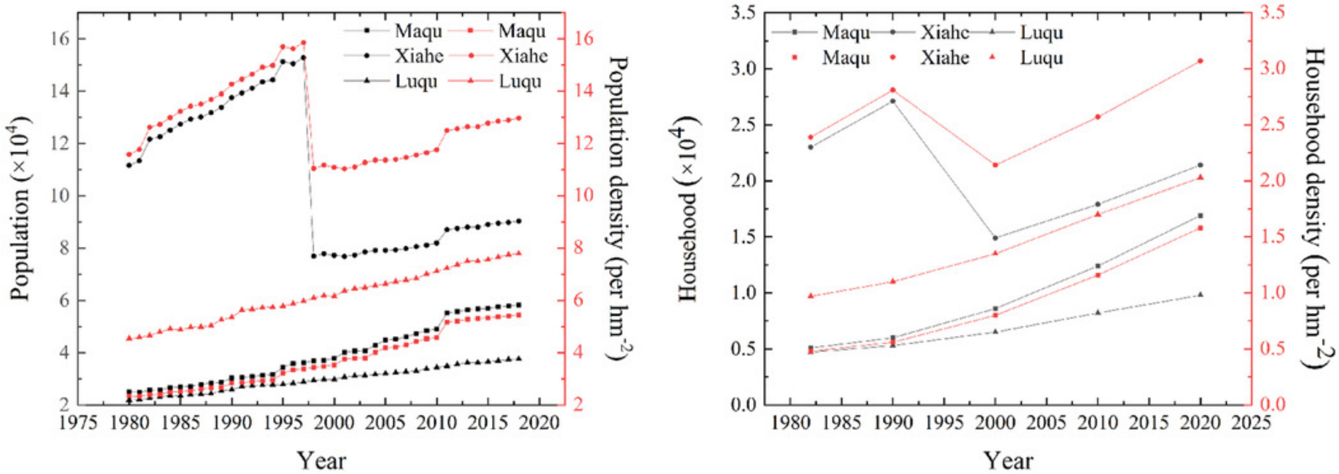


Figure 13

Changes in population structure in the counties of Maqu, Luqu and Xiahe.

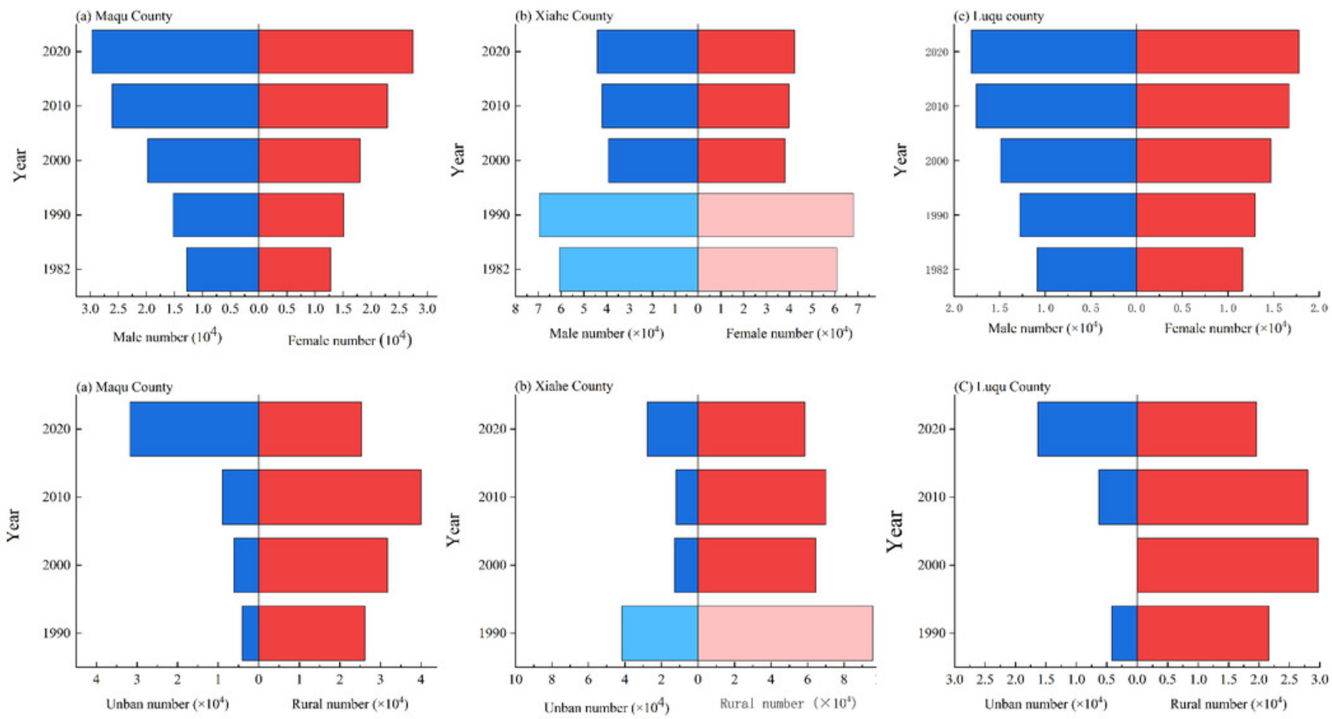


Figure 14

Changes in education levels in the counties of Maqu, Luqu and Xiahe

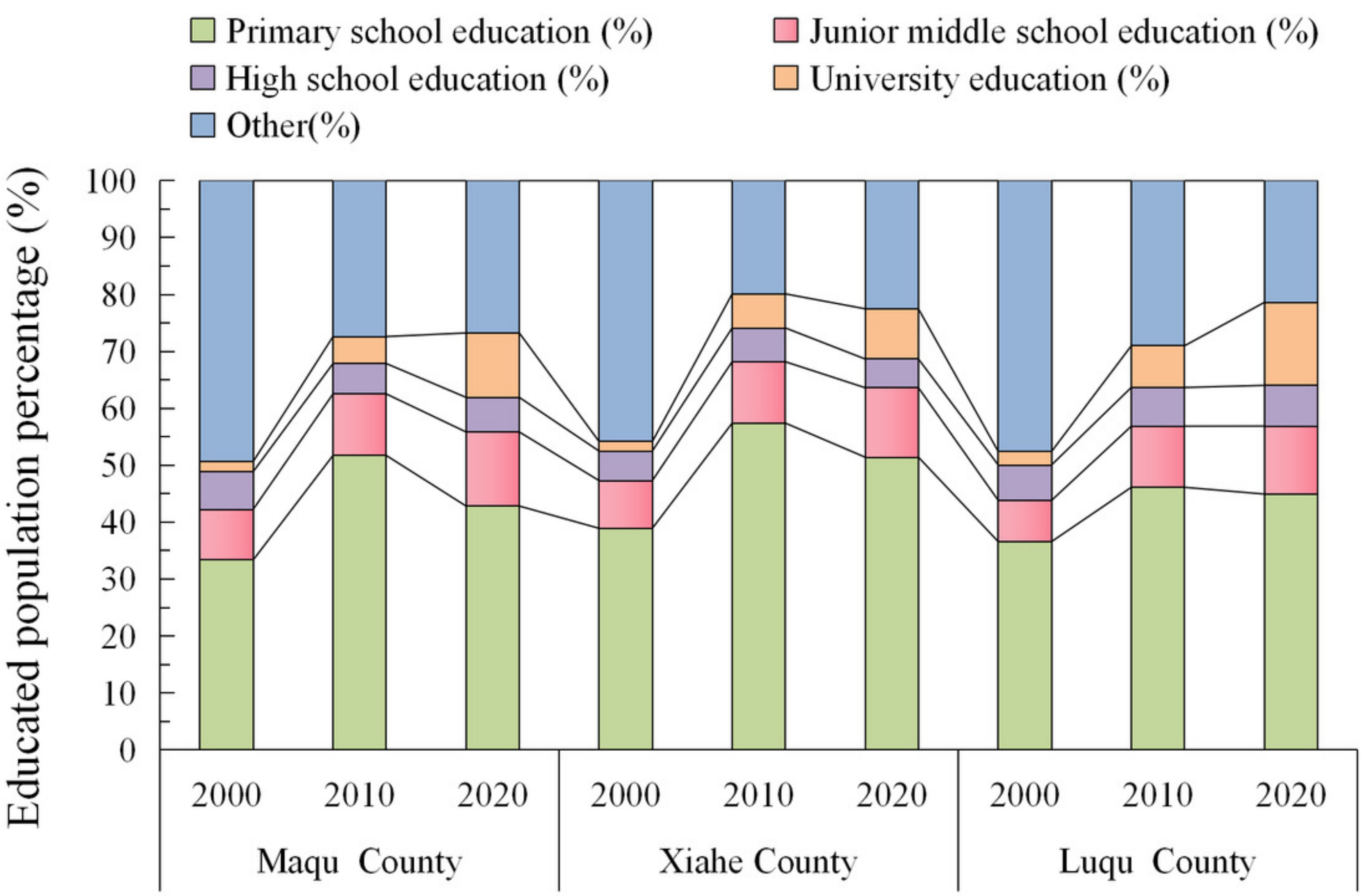
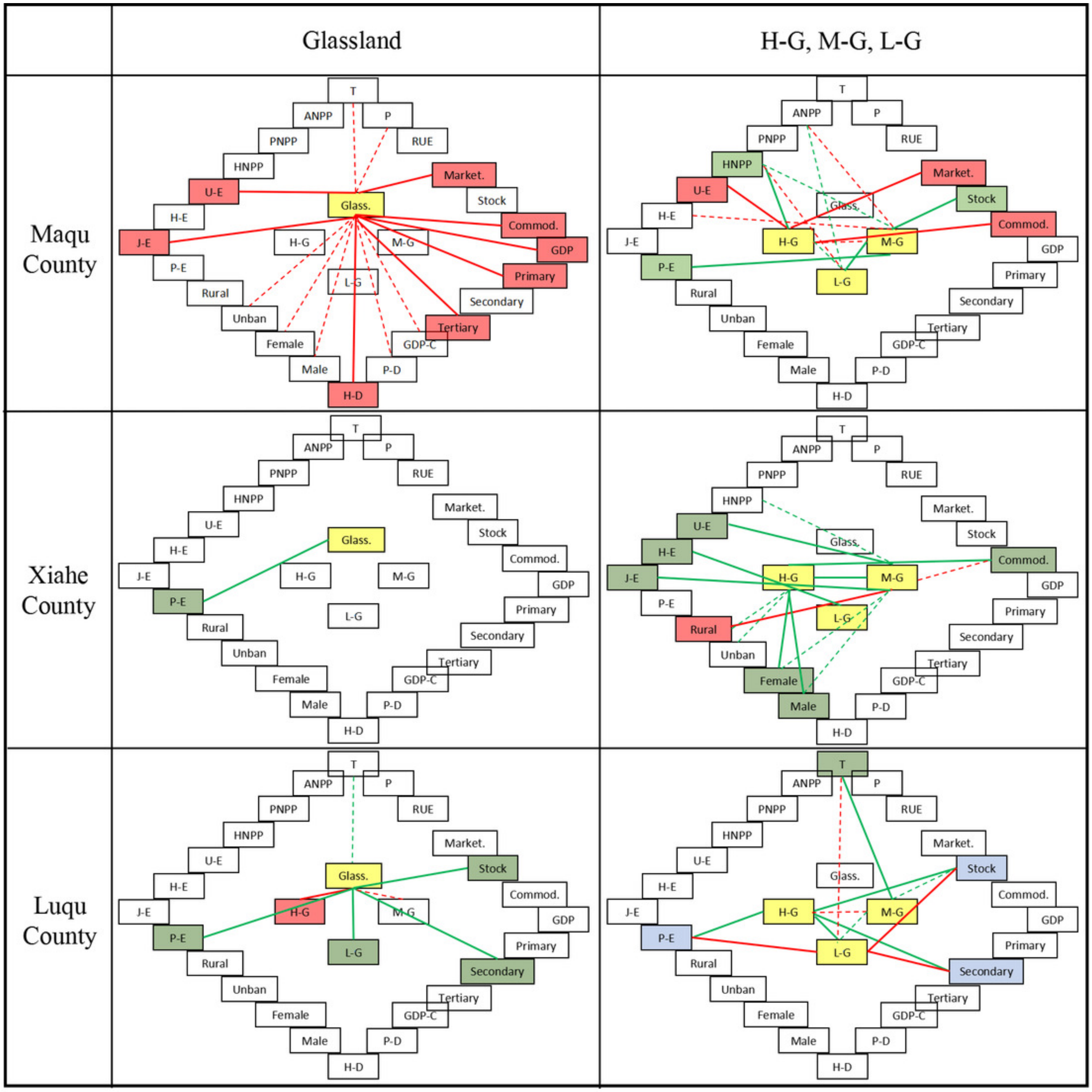


Figure 15

Correlation analysis of climate and socioeconomic parameters.

* and ** represent significance at the 0.05 and 0.01 (two-tailed) level, respectively; Cult., Grass., U/R, H-G, M-G, L-G, T, P, Marketing, Stock, Commodity, Primary, Secondary, Tertiary, Population-D, Household-D, P-E, J-E, H-E and U-E represent cultivated land, grassland, urban–rural residential land, high coverage grassland, medium coverage grassland, low coverage grassland, temperature, precipitation, numbers of livestock marketing, numbers of livestock stock, commodity rate, primary industry, secondary industry, tertiary industry, population density, household density, primary school education, junior middle school education, high schooleducation and university education, respectively.



—— and ------ represent positive significance at the 0.05 and 0.01 (two-tailed) level,
—— and ------ represent negative significance at the 0.05 and 0.01 (two-tailed) level.

Table 1(on next page)

Areas of different land cover classification in the counties of Maqu, Xiahe and Luqu (hm^2).

Region	Year	Cultivated land	Forest	Grassland	Water area	Urban–rural residential land	Unutilized land
Maqu County	**1980**	0.69	844.07	7796.12	186.14	4.69	1870.22
	1990	0.70	862.11	7793.97	172.82	4.69	1867.65
	2000	2.10	855.10	7805.95	163.28	6.07	1869.45
	2010	1.58	855.62	7813.45	199.96	12.56	1818.79
	2018	1.59	856.71	7837.28	175.88	16.48	1790.38
Xiahe County	**1980**	268.49	2137.58	4399.44	8.22	28.26	122.03
	1990	269.06	2137.87	4398.58	8.24	28.27	122.02
	2000	338.16	2045.11	4421.13	8.30	30.50	120.98
	2010	332.54	2050.28	4389.81	8.20	35.74	147.58
	2018	330.11	2055.93	4402.46	8.13	39.07	123.75
Luqu County	**1980**	14.00	1061.17	3489.63	21.10	6.23	233.58
	1990	14.00	1060.42	3489.98	21.10	6.23	233.97
	2000	27.57	1047.37	3489.51	18.73	7.69	234.84
	2010	38.11	1069.01	3420.08	35.02	12.34	251.23
	2018	28.69	1070.00	3446.40	34.67	15.54	221.45

Table 2 (on next page)

Changes in different ecosystem vulnerability levels of grassland in the counties of Maqu, Xiahe and Luqu (hm^2).

Year	Maqu County			Xiahe County			Luqu County		
	High coverage grassland	Medium coverage grassland	Low coverage grassland	High coverage grassland	Medium coverage grassland	Low coverage grassland	High coverage grassland	Medium coverage grassland	Low coverage grassland
1980	1955.13 (25.08%)	4643.53 (59.56%)	1197.47 (15.36%)	2524.10 (57.37%)	1795.36 (40.81%)	79.99 (1.82%)	2811.68 (80.57%)	677.96 (19.43%)	0.00 (0.00%)
1990	1951.08 (25.03%)	4647.64 59.63%)	1195.26 (15.34%)	2522.73 (57.35%)	1796.04 (40.83%)	79.81 (1.81%)	2811.56 (80.56%)	678.42 (19.44%)	0.00 (0.00%)
2000	1893.22 (24.25%)	4481.51 57.41%)	1431.23 (18.34%)	2589.12 (58.56%)	1750.35 (39.59%)	81.66 (1.85%)	2813.51 (80.63%)	676.01 (19.37%)	0.00 (0.00%)
2010	1898.10 (24.29%)	4468.17 (57.19%)	1447.19 (18.52%)	2587.01 (58.93%)	1745.36 (39.76%)	57.44 (1.31%)	2752.18 (80.47%)	667.54 (19.52%)	0.36 (0.01%)
2018	1917.09 (24.46%)	4472.18 (57.06%)	1448.02 (18.48%)	2577.58 (58.55%)	1740.63 (39.54%)	84.25 (1.91%)	2771.50 (80.42%)	674.68 (19.58%)	0.22 (0.01%)

Table 3 (on next page)

Correlation analysis of land types.

* and ** represent significance at the 0.05 and 0.01 (two-tailed) level, respectively; Cult., Grass., U/R, H-G, M-G and L-G refer to cultivated land, grassland, urban–rural residential land, high coverage grassland, medium coverage grassland, and low coverage grassland, respectively.

		Cult.	Forest	Grass.	Water	U/R	Utilize.	H-G	M-G
Maqu Couty	**Forest**	0.196							
	Grass.	0.552	0.186						
	Water	-0.241	-0.313	0.054					
	U/R	0.458	0.221	0.955*	0.312				
	Utilize.	-0.356	-0.232	-0.934*	-0.349	-0.993**			
	H-G	-0.961**	-0.236	-0.505	0.013	-0.492	0.397		
	M-G	-0.922*	-0.214	-0.763	-0.059	-0.745	0.667	0.942*	
	L-G	0.922*	0.224	0.771	0.045	0.750	-0.672	-0.938*	-1.000**
Xiahe Couty	**Forest**	-1.000**							
	Grass.	0.315	-0.299						
	Water	-0.096	0.100	0.585					
	U/R	0.721	-0.723	-0.223	-0.755				
	Utilize.	0.396	-0.414	-0.645	-0.248	0.452			
	H-G	0.997**	-0.998**	0.289	-0.064	0.696	0.446		
	M-G	-0.979**	0.979**	-0.182	0.298	-0.847	-0.429	-0.969**	
	L-G	-0.263	0.282	0.627	0.061	-0.237	-0.973**	-0.325	0.264
Luqu Couty	**Forest**	0.289							
	Grass.	-0.844	-0.749						
	Water	0.718	0.862	-0.954*					
	U/R	0.735	0.681	-0.833	0.923*				
	Utilize.	0.429	0.027	-0.395	0.124	-0.156			
	H-G	-0.823	-0.779	0.998**	-0.970**	-0.854	-0.348		
	M-G	-0.912*	-0.487	0.925*	-0.771	-0.626	-0.669	0.901*	
	L-G	0.843	0.748	-1.000**	0.952*	0.827	0.404	-0.998**	-0.927*

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