The distribution and land use characteristics of alluvial fans in Lhasa River Basin in Tibet

Tongde Chen[1], Ju-Ying Jiao[2], Yixian Chen[3], Hong Lin[1], Haoli Wang[1], and Leichao Bai[1]

[1]Northwest A&F University
[2]Northwest A & F University
[3]Institute of Soil and Water Conservation Chinese Academy of Sciences and Ministry of Water Resources

July 16, 2020

Abstract

The land that is suitable for settlement or live is shortage in Lhasa River Basin (LRB). Alluvial fan is a candidate resource to suitable land in this situation. However, the basic information of alluvial fans, for example its distribution and land-use types, is little known. In this study, Google earth, ArcGIS and visual interpretation were used to get the outlines, areas, quantity and distribution of alluvial fans. Meanwhile, the land use, the distance from alluvial fans to roads, places (town and village) and rivers (including stream) are analyzed. The results show that there are 826 alluvial fans in LRB and the total area is 1166.03 km². The quantity of alluvial fans with area between 0.1 km2 and 1 km2 is 517, which is dominated in all. The quantity of alluvial fans is concentrated in the east of LRB, but that area is mainly distributed in the west. The area of Grassland is the largest in all land use types which is account for 68.70% of alluvial fans. Although cropland area is accounted by 2.16% of alluvial fans, it is accounted by 18.98% of the LRB's cropland area. The quantity of alluvial fans within in 5km distance to tertiary road, village, and river (including stream) are accounted of 93.70%, 53.63% and 77.38% respectively. Therefore, alluvial fans have played an import role in LRB, and may have huge utilization potential in the future.

1 Introduction

Alluvial fan is a fan landform which surface forms a cone deposit that radiates downslope (Bull, 1977). It is consisted of solid material eroded from an upland catchment (Ashworth, 2006). Alluvial fans can be developed in many types of terrestrial settings, such as alpine, humid tropical, humid mid-latitude, periglacial and different paraglacial settings (Dorn, 1994). There are many factors for alluvial fans development. The area, slope gradient, bedrock types, geology characteristics of catchment effect the landform material of alluvial fan (Blair, 2002; Stock et al., 2008). For example, there are two adjoining alluvial fans in the Death Valley of California, and one is formed through flooding processed and another is through debris flow processed just because of the different of bedrocks with the other almost similarity. At the same time, the average slope of flooding-processed fan is lower than debris-processed fan, but the area, radius is opposite. Besides, the material of former is mainly composed by Andesite and Granite, but the latter is mainly Precambrian to Cambrian sedimentary rocks (Blair, 2002). Regional tectonic and climate effect the deposit process and geomorphology of alluvial fans (Bull, 1977). Tectonic forces effect the morphology by controlling the scale of accommodation space and organizational types of deposit material (Sarp, 2015). The increasing aridity in the Late Pleniglacial result that the alluvial fan is small-scale in central Europe, and the scale is more in the humid times (Sarp, 2015). Even though existing many factors for alluvial fan's formation, the more directly factor for alluvial fans are runoff flow, including river, flood and debris flow. Accordingly, there are mainly three types about forming process of alluvial fans, including fluvial process, flooding process and debris flow process (Birch et al., 2016; Dickerson et al., 2013; Santangelo et al., 2012).

The land that is suitable for settlement or cultivation is shortage due to harsh climate and natural hazards in many mountain regions, but some area, like alluvial fans, also have possibilities about better hydrological conditions, fertile soil, relatively flat terrain and so on (Khan et al., 2013; Mazzorana et al., 2020; Rahaman, 2016; Telbisz et al., 2016). Therefore, alluvial fans are priority among settlement areas or cultivation in many mountain regions (Ma et al., 2004; Mazzorana et al., 2020). Even some large-scale alluvial fans are used to develop cities or towns (Chen et al., 2017; Maghsoudi et al., 2014; Santangelo et al., 2012). Besides, alluvial fans include kinds of solid materials from clay, slit to sand, gravel and large boulders, so some are regarded as construction resources (Bahrami et al., 2015). Hence, alluvial fan is an important land resource although few researches could focus on this point. Moreover, alluvial fans are threatened by some types of natural hazards because of special forming processes and environments. And natural hazards vary among different-processed alluvial fans. The fluvial-processed alluvial fans can easily develop some cities due to relatively plenty water resource including groundwater. So, the land subsidence, water shortage and pollution are commonly natural hazards in those alluvial fans because of long-term overutilization and contamination of water resource (Alkinani et al., 2019; Bull, 1973; Chen et al., 2017). The surface of flooding-processed and debris-flow-processed alluvial fans are more taken in the risk of floods (Dickerson et al., 2013; Santangelo et al., 2012), debris flows (Khan et al., 2013; Okunishi & Suwa, 2001), or gully erosion (Deng et al., 2019). That is to say, those 2 types of alluvial fan are formed by debris flow or flood processing, meanwhile the surfaces of alluvial fans are threatened by hazards due to those processings. Indeed, alluvial fans exist above natural hazards, but they are still used in kinds of ways. The contradiction also reflects the fact the available land is shortage in some mountain regions. Therefore, alluvial fan is an important land resource although few researches focused on this point. The studies about survey, protection, plan and reasonable utilization of alluvial fans need to be down more.

Tibet plateau is the highest region in the earth, and the majority of land in Tibet isn't suitable for local human to use and live, because of the extreme and vulnerable environment, which means the land is limited for development (Liang & Hui, 2019). A good habitability of mountain regions is based on hydrological, geomorphological, biogeographical properties and so on ((Telbisz et al., 2016). Only terraces, alluvial fans and gentle-slope maintain areas can basically satisfy those properties in Tibet, but the terraces have been well utilized due to better gentle terrain, fertile soil and hydrological conditions. For this reason, the area that suitable to local human to live is more finite in Tibet. Meanwhile, the population is dramatically increasing, and Tibet has been in an accelerated urbanization stage in recent years (Fan et al., 2010). Therefore, the human-environment interaction is gradually becoming to uncoordinated state due to shortage of the land for cultivation and settlement (Liang & Hui, 2019). Many farmlands and villages are distributed in alluvial fans, although they are threatened by floods and gully erosion (Ma et al., 2004). In order to relieve this problem, alluvial fans located in Tibet need to be focused. However, researches about alluvial fan is rarely, even though alluvial fan is an important land resource in Tibet. The quantity, distribution and land use of alluvial fans in this region are insufficiently understood, but it is important to know, use and protect this land resource. Lhasa city is the capital of Tibet in China and is located in Lhasa River Basin (LRB), where the need for land is urgent. So, we chose this basin to investigate the amount, distribution and land use of alluvial fans. Meanwhile, the distance from alluvial fans to different scale of roads, places (town and village) and rivers are analyzed to illustrate the value, function and utilization potential of this land resource in LRB.

2 Methods

2.1 Study area

The study area is Lhasa River basin (LRB) with 32 471km^2, located in the south of Tibet Autonomous Region, the southwest of China, lying from 29°20'N–31deg15'N 90deg05'E–93deg20'E (Figure 1). This area is consisted of Chenguan, Tolung Dechen, Taktse, Medro Gongkar, Lhundup, Dumshung and a part of Seni, Chali and Chushur county, as shown in Figure 1. The altitude of study area is varied from 3500m to 7162m (Zhang et al., 2010). The majority altitude of this area is over 4000m, while the middle and downstream of Lhasa river valley are less 4000m (Wei et al., 2012). It belongs to plateau temperate semi-arid monsoon climate region and the average temperature is about -1.7-9.7(Zhang et al., 2010). The annual precipitation is about 340-600mm and concentrated form June to September (Wei et al., 2012). The vegetations are characterized by alpine steppe, alpine meadows and alpine shrub shrubs, cushion vegetation and so on (Lin et al., 2008). There are seven soil types of this region: alluvial soil, meadow soil, subalpine steppe soil, subalpine meadow soil, alpine steppe soil, alpine meadow soil and alpine frozen soil. Those soil types are corresponded with Fluvaquents, Haplumbrepts, Calcic cryoboroll, Typic cryaquept, Cryuborolls, Cryaquoll and Aridisols in the USA taxonomy. The first former types of soil are arable land soil that can be planted with winter barley (*Hordeum vulgare L*), winter wheat (*Triticum aestivum L*), and maize (*Zea mays L*) (Wei et al., 2012).

The terrain of northwest is higher than the southeast, and the landform is combined with mountains, valleys, river terraces, alluvial fans and so on (Dai et al., 2018; Wei et al., 2012). Terraces and alluvial fans are lower than mountains, and most of the arable land is located in these lower areas (Wei et al., 2012). Besides, the investigation in 2018 (Ma et al., 2018) is showed that: 1) alluvial fan is a common landform in the valleys of LRB; 2) many villages and farmlands are located in alluvial fans; 3) the land-use scale of alluvial fan is lower than river terrace that has been sufficiently used to develop towns and cities.

2.2 The extraction of alluvial fans

The alluvial fans were drawled by visual interoperation in Google Earth Pro (7.3.3.7692). The standard about visual interoperation was the three obvious characteristics of alluvial fans formed by flooding process in LRB: (1) fan-shaped landform, (2) braided flow channels, and (3) none consistent flow, as shown Fig2.. According those characteristics, the outline data is got in Google Earth Pro. Then added outline to ArcGIS to get the data about area, position and distribution of alluvial fans.

2.3 Data sources

The data of land use type in 2017 was 10-m resolution and got from*http://data.ess.tsinghua.edu.cn/*, which was 72.76% in overall accuracy (Gong et al., 2019). The land use types were classified into cropland, forest, grassland, shrubland, wetland, water body, tundra, impervious area, bare land, and snow/ice (Gong et al., 2019).

The position data about road, place and waterway were got form Openstreetmap (*https://www.openstreetmap.org/*). In this website, the roads were classified into trunk road, primary road, secondary road, tertiary road, residential road, cycleway, footway and so on (*http://wiki.openstreetmap.org/wiki/Key:highway*). The places were classified into country, province, county, town, village and so on (*https://wiki.openstreetmap.org/wiki/Key:place*). The waterway were classified into river, stream, drain, ditch and so on (*https://wiki.openstreetmap.org/wiki/Key:waterway*).

2.4 Data processing and analysis

2.4.1 The classification of alluvial fans.

The quantity of alluvial fans was large, and the area had lots of sizes in our study area. In order to know the distribution of them, they were classified into five sizes by the area of alluvial fans, i.e., 1^{st}: area[?]0.1 km2, 2^{nd}: 0.1¡area[?]1 km2, 3^{rd}:1¡area[?]10 km2, 4^{th}: area¿10 km2. And the quantity of all the sizes was counted.

2.4.2 Indicators for the land use

There were many types of land use in alluvial fans, for example cropland, forest, grassland, shrubland, wetland, water body, tundra, impervious area and bare land. In order to reflect the land use characteristics of alluvial fans in LRB, the two indicators ofR_{laf} and R_{llrb} were used.R_{laf} was the ratio between the area of a land-use types in alluvial fans and the total area of alluvial fans.R_{llrb} was the ratio between the area of a land-use type in alluvial fans and the area of the same land-use type in LRB.

$R_{laf} = A_{li}$ / Aa*100% (1)

Where A_{li} (km2) was the area of land use $i$of alluvial fans; and i= cropland, forest, grassland…;Aa (km2) was the total area of alluvial fans.

$R_{llrb} = A_{li} \ / A_{lrbi}$ *100% (2)

Where A_{li} (km2) was the area of land use $i$of alluvial fans, and i= cropland, forest, grassland…;A_{lrbi} (km2) was the area of land use i of LRB.

Meanwhile, in order to show the spatial distribution of land-use types in alluvial fans, the alluvial fans are classified into 2 types by the area of land-use type. The first type is the alluvial fans which area are occupied as one land use i not less than 50% ($A_{50\%i}$), and i= cropland, forest, grassland…. The second type is the $A_{50\%i}$ which area are occupied as another land use j not less than 30% ($A_{50\%\ i}$ $A_{30\%\ j}$), and$j$= cropland, forest, grassland….

2.4.3 Indicators for utilization potential.

The utilization potential is mainly depending on the distance between an area and road, place and waterway. The centroids of all alluvial fans were calculated in ArcGIS and used to analysis the distance between alluvial fan and road, place and waterway respectively. According to the fact of road in LRB and the needs of our study, the primary road, secondary road, tertiary road, county, town and village were chosen to analyses the distances. For the town and village, the places of their government departments were used to get the distance. Meanwhile, considering the background of water shortage in semi-arid monsoon climate region, all kinds of waterways are important for this basin. So, the data of stream with consistent low were added to the river data for analyzing.

Another two ratio indicators including R_q andR_a are used to show the utilization potential of alluvial fans. R_q is the ratio between the quantity of alluvial fans that their distance to road, place and river are not more than some space and the total quantity of alluvial fans in LRB. Ra is the ratio between area of alluvial fans that their distance to road, place and river not more than some space and total area of alluvial fans.

$R_q = Q_{an} \ / Q$ *100% (3)

Where Q_{an} is the quantity of alluvial fans not more than n (km) to road, place and river, and n= 1, 5, 10, 20, 40; Q is the total quantity of alluvial fans.

$R_a = A_{an} \ / A_a$ *100% (4)

Where A_{an} (km2) is the area of alluvial fans not more than n (km) to road, place and river, and n= 1, 5, 10, 20, 40; Aa (km2) is the total area of alluvial fans in LRB.

All figures are carried out with ArcGIS10.7 and Origin 8.5 software.

3 Results

3.1 The quantity of alluvial fans

The quantity of alluvial fans with different size is provided in Fig.3. As a whole, there are 826 alluvial fans in LRB. The number of 2^{nd} size (0.1 km2¡area[?]1 km2) is the most in all the sizes with a number of 517, and it's proportion is 62.59%. And then, the number of 3^{rd} size (1 km2¡area[?]10 km2)is the second with a number of 205. The number of 4^{th} (area¿10 km2) is 17, just only accounted for 2.06% in the total alluvial fans. That means the alluvial fans with area less than 1 km2are dominated, and with area more than 10 km2are in LRB.

Furthermore, the alluvial fans are ranked by area from small to large, and there is an exponential relationship (the equation: $y=3.93e^{0.067x}$, R^2=0.92) between accumulating area with quantity of alluvial fans, which is showed in Fig4. It is found that the accumulating area of alluvial fans is 83.39 km^2, when the quantity accounting for 50% of total quantity of alluvial fans. Furthermore, the quantity of alluvial fans is 746.27, when the area accounting for 50% of total area with 1166.03 km^2, which indicates that the area is occupied by 26 large-size alluvial fans (4^{th}).

3.2.1 Quantity and area distribution

The quantity of alluvial fans is concentratedly distributed in the center and east of LRB, especially in the Lhundup and Medro Gongkar and south of Chali county (Fig5.a). The number of alluvial fans in those three counties is 452, accounting for 54.72% in all alluvial fans. However, the distributing trend of area is contrary with quantity (Fig5.b). Compared with the east, the large area is in the west, especially in Damshung county, and the area proportion of all alluvial fans is 41.61% of total area. Besides, there are a great number of alluvial fans in Medro Gongkar and Chali county (156 and 122), however, the area is small (89.95 km2and 60.42 km2),and their proportion in all alluvial fans' area are 7.71% and 5.18%, respectively.

3.2.2 The spatial distribution of different size alluvial fans

The spatial distribution of different size alluvial fans is shown in Fig.6. The 1^{st} to 3^{rd} size of alluvial fans almost exist in all counties in LRB, and the 4^{th} size exists 4 counties. The quantity of 1^{st} alluvial fans mainly distributes in the east (Medro Gongkar and Chali county), and are rare in the west and south (Fig. 6a). The quantity of 2^{nd} alluvial fans is largely distributed in Lhundup, Modero Gongkar, and Chali (Fig. 6b). Besides, the 2^{nd} ones relatively have more quantity in those three counties than other sizes. The 3^{rd} mainly distributes in the Damshung and Lhundup county (Fig.6c). The quantity of 4^{th} is a few than other sizes, and are sporadically distributed in the Damshung and Lhundup couty (Fig.6d). Especially, the 4^{th} alluvial fans existed in the Damshung county just are 10 with the area of 361.61 km2, which is account for 31.01% of total area of alluvial fans.

3.3 The land use of alluvial fans

The Table 1 shows the area proportion of different land use types of alluvial fans in LRB. The R_{laf} of grassland is the largest with 68.70% in all land-use types. TheR_{laf} of impervious area covered by artificial buildings is only 4.52%, but R_{llrb} is 9.18%. The R_{laf} and R_{llrb} of cropland had similar regulation with impervious area. TheR_{laf} of cropland is just 2.16%, butR_{llrb} is 18.98% of the cropland area of LRB. Those illustrate the great contribution of alluvial fans about providing grass for livestock and food and residential place for human. TheR_{laf} and R_{llrb} of forest, shrubland, wetland, and water body are far lower than cropland, impervious area and bare land. The snow/ice almost can be ignored in all types of land use.

The spatial distribution of land-use types of alluvial fans is showed in Fig7. The grassland is the most in all land use types, especially in Damshung cunty. The cropland is mainly distributed in the south of LRB, including Taktse, Tolung Dechen, Chushur and the south part of Lhundup county. The distribution of imperious area is the same with cropland, including Taktse, Chenguan and Tolung Dechen. The bare land is mainly distributed in Damshung and Chushur county. Combining Google earth, the bare land of alluvial fans is covered by sand where is hardly grow vegetation.

There are only 3 kinds of alluvial fans which area are occupied more than 50% by one land-use type ($A_{50\%,}$), including $A_{50\%\text{grassland}}$, $A_{50\%\text{impervious area}}$, and $A_{50\%\text{cropland}}$ (Fig8.). The $A_{50\%\text{grassland}}$ exist all counties with 665 and area of 903.17 km2. The $A_{50\%\text{impervious area}}$ only exist in Tolung Dechen, Chenguan, and Taktsc. There is only an $A_{50\%\text{grassland}}$ in LRB with the area of 0.07 km2. There are 6 kinds of $A_{50\%}$ which area are occupied more than 30% another land-use type ($A_{50\%}A_{30\%}$), and 4 kinds are about $A_{50\%\text{grassland}}$ (Fig9.) the quantity of $A_{50\%}$ $A_{30\%}$ is far less than $A_{50\%}$. $A_{50\%\text{grassland}}A_{30\%\text{bare land}}$ is the most in $A_{50\%}A_{30\%}$, and distribute all counties except ChuChur. The $A_{50\%\text{impervious area}}$ $A_{30\%\text{bare land}}$ and the $A_{50\%\text{impervious area}}$ $A_{30\%\text{grassland}}$distribute in Tolung Dechen and Chenguan.

3.4 The distance of alluvial fans to road, place and river

Fig.10 shows the trend of the quantity and area proportion of alluvial fans with the distance to different grade road. For primary road, theR_{q1} is 29.66%, and the R_{d1} is 21.83%. When the distance is not more than 5km,R_q and R_d are dramatically increasing. The R_{q5} reach 75.91%, and the area proportion is 89.87 %. Furthermore, for tertiary road, the regulation is same with primary road. R_{q1} , $R_{d1}$and R_{q5} ,R_{d5} are 66.71%, 44.97% and 93.70%, 97.50% respectively. Therefore, the great majority alluvial fans are adjacent to road with distance not more than 5km.

Fig.11 shows the trend of the quantity and area proportion of alluvial fans with the distance to towns and villages. TtheR_{q1} andR_{d1} to towns just are 1.94% and 1.59%, even theR_{q5} and R_{d5} are 34.62% and 36.30%. After the distance recaching 10 km, theR_q and R_d exceed 50%. That means the majority of alluvial fans are mainly distributed in the regions with the distance to town over 5km. However, theR_{q5} and R_{d5} to village are 53.63% and 46.14%, reflecting about half of alluvial fans are near with villages.

Fig.12 shows the trend of the quantity and area proportion of alluvial fans with the distance to river. The R_{q1} andR_{d1} are 23.66% and 21.83%, and theR_{q5} and R_{d5} have been 61.86% and 77.38%. That can reflect the majority alluvial fans have a near distance to water resources.

4.Discussion

4.1 The quantity, area and distribution of alluvial fans

There are many sizes of alluvial fans in LRB, and the distribution of quantity and area is uniformed. The formation and development of alluvial fans base the catchment characteristics, tectonics and climate (Sarp, 2015). The size of alluvial fans is major determined by the characteristics of catchment (Mather et al., 2016). Typically, the larger alluvial fans have larger and gender catchment with greater possibility to accumulate to sediment flows. Moreover, the catchments of smaller alluvial fans are smaller and steeper, which the ability of storing slope deposits is limited (Mather et al., 2016). And this regulation needs to be verified in LRB. As above, the sediment flow is a direct factor for alluvial fan. The mountain including many catchments of alluvial fan is covered by ice and glaciers throughout the year in the west of LRB. Especially, the area of ice and glaciers of Damshung is largest in LRB with 535.95 km^2 in 2010 (Xu, 2013), so the water (meltwater) carrying sediment is enough. The ice or glaciers in LRB except Daumshung are shortage because the majority of elevation of those regions is not more than 4000m (Wei et al., 2012). Therefore, the size of alluvial fans in the west is more than other regions in LRB. Furthermore, the exist of ice or glaciers should be an important factor for the sizes of alluvial fans.

Meanwhile, the size and uniformed distribution of alluvial fans may be caused by tectonic activity. The topographic uplift of Damshung area is earlier than other area in LRB ((Wang et al., 2017), which induce a difference of accommodation space of alluvial fan and fan catchment due to tectonic force (Sarp, 2015). The size, distribution, formation and development of alluvial fan should be studied in next step.

4.2 The land use of alluvial fan

Alluvial fan is an important land resource in LRB, even in Tibet region. There are mainly 4 types of landforms in LRB: mountains, valleys, river terraces and alluvial fans (Dai et al., 2018; Wei et al., 2012). The river terrace and alluvial fan land are easier utilized than mountain land, because of high altitude and severe ecological environment in LRB. Compared with alluvial fan land, the river terrace land has the priority in the utilization for the slow slope, fertile soil and near position of river. Therefore, the majority of towns and farmlands locate in the river terraces. The alluvial fans are formed by sediment exiting confined valley after the function of flooding (Stock et al., 2008), so that it has naturally slope. And the soil of some alluvial fans are less fertile due to the effect of repeated flooding and depositional processes (Bahrami & Ghahraman, 2019). However, the area of cropland and impervious area of alluvial fans account for 18.98% and 9.18% of their area in LRB (Table1). Moreover, although the ratio between grassland of alluvial fans and grassland of LRB is just 3.97%, the area of grassland of alluvial fans can reach 790.57 km^2. Those characteristics reflects a fact that the land for living and producing is indeed shortage in LRB, and alluvial fans have been an important role in local. It is reported that there is a dramatically gap between the land requirement of local human and the area of available land in Lhasa area, especially near the major towns and the Lhasa valley (Chu et al., 2010). However, the available land, especially river terrace land is not unlimited in LRB facing the state that river terraces have been relatively adequate utilized. Therefore, the other type of easily available land like alluvial fans could be an important land resource reserve. The population and economy are quickly increasing in recent years (Wei et al., 2017), enhancing the importance of alluvial fan will be more in the future.

4.3 The utilization potential of alluvial fans

The distances between alluvial fans and road, human settlement and water system are important factors effecting the utilization potential of alluvial fans. The transport network density of Tibet is lowest among all the provinces of China (Jin et al., 2010), which indicates that transport roads are sparse in LRB. However, the quantity percentage of alluvial fans distanced to primary road and tertiary road not more than 5 km are 79.51% and 99.72% (Fig.10), so the most of alluvial fans are easy to access. LRB has a typical semi-arid frigid climate (Lin et al., 2008), so water resource is an important factor for regional development. The quantity percentage of alluvial fans distanced to river not more than 5km reach 61.86% in this semi-arid basin (Fig.12). It's showed the majority of alluvial fans will be appropriate for agricultural or residential development from the water perspective. There is a situation should be focused that some rivers located between roads and alluvial fans. For the utilization, those rivers have two functions, of providing water resource and cutting the accessibility to alluvial fans in this situation. In order to adequately use those alluvial fans, some bridges could be built in the future.

The area of grassland and bare land in alluvial fans is 802.59 km^2, and the area of alluvial fans which is occupied by grassland not less than 50% ($A_{50\%\text{grassland}}$) even reach to 903.17 km2. The land-use degree of grassland and bare land is lower than cropland and imperious area (Zhuang & Liu, 1997). So those two types of alluvial fans, $A_{50\%\text{grassland}}$ and $A_{50\%\text{grassland}}$ $A_{30\%\text{bare land}}$, should be more utilization potential based on reasonable explorations. Besides, the utilization potential of the alluvial fans located in the west and south of LRB should be focused. There are many $A_{50\%\text{grassland}}$ (Fig.8), and near rivers in the west (Fig.1). Therefore, alluvial fans in Damshung may be more protentional in the future. The Chenguan is an urban area of Lhasa city which is capital of Tibet located in the south of LRB. And the government residences of Tolung Dechen, Chushur and Taktse are near with Chenguan. Therefore, the south of LRB especially near Chenguan should be more needed for available land than another region. There are alluvial fans with 243 km2in the region, meanwhile some bare land are located in those alluvial fans. So, the alluvial fans in this part may be utilized adequately the future.

5. Conclusions

In this study, the alluvial fan is confirmed further to be an important land resource and still has utilization potential in RRB. The main conclusions are as follows:

(1) There are 826 alluvial fans with 1166.03 km2in LRB. The quantity of all alluvial fans is dominated by the ones with area not more than 1 km2, but the area of alluvial fans is dominated by the ones with area more than 10 km^2.

(2) The distribution of alluvial fans is uniformed in LRB. The quantity of alluvial fans is concentratedly distributed in the center and east in LRB, and the area distribution trend is opposite with quantity. Especially in Damshung county in the west of LRB, the area of alluvial fans is 485.20 km^2.

(3) Alluvial fans provide materials and places for local human and livestock to exist and settlement. The area of grassland is the most in all land-use types. The area ratio of cropland and imperious area in alluvial fans are just 2.16% and 4.52%, but which in LRB are 18.98% and 9.18%.

(4) The two types of alluvial fans have the more utilization potential in the future due to their considerable area and low land-use degree. The first one is alluvial fans which is occupied by grassland no less than 50%. And second one is alluvial fans which is occupied by grassland and bare land not less than 50% and 30%. Meanwhile, considering the accessibility of alluvial fan, the majority of alluvial fans are located within 5 km to road, village and river. The quantity ratio of alluvial fans distance to tertiary road, village and village within 5km are 93.70%, 53.63% and 61.86% respectively, and area ratio are 97.50%, 46.14% and 77.38%, respectively. Therefore, alluvial fan has the utilization potential in LRB where the suitable land for human is shortage.

Acknowledgments : This research was supported by the Strategic Priority Research Program of Chinese Academy of Sciences(No. XDA20040202)and the second Tibetan Plateau Scientific Expedition and Research

Program (STEP) (No. 2019QZKK0603)

References

Alkinani, M., Wiche, O., Kanoua, W. & Merkel, B. (2019). Sequential extraction analysis of U, Sr, V, Ni, Cr, B, and Mo in sediments from the Al-Batin Alluvial Fan, Southern Iraq. *Environmental Earth Sciences* , 78, 1-13. https://doi.org/10.1007/s12665-019-8730-1.

Ashworth, P. (2006). Alluvial Fans: geomorphology, sedimentology, dynamics by Adrian Harvey, Anne Mather, Martin Stokes. *Area* , 38, 225-226. https://doi.org/10.1111/j.1475-4762.2006.690_5.x.

Bahrami, S. & Ghahraman, K. (2019). Geomorphological controls on soil fertility of semi-arid alluvial fans: A case study of the Joghatay Mountains, Northeast Iran. *Catena* , 176, 145-158. https://doi.org/10.1016/j.catena.2019.01.016.

Bahrami, S.B.S., Aghda, S.A.S.M., Bahrami, K.B.K., Rad, M.R.M.M. & Poorhashemi, S.P.S. (2015). Effects of weathering and lithology on the quality of aggregates in the alluvial fans of Northeast Rivand, Sabzevar, Iran. *Geomorphology* , 241, 19-30. https://doi.org/10.1016/j.geomorph.2015.03.028.

Birch, S.P.D., Hayes, A.G., Howard, A.D., Moore, J.M. & Radebaugh, J. (2016). Alluvial Fan morphology, distribution and formation on Titan.*Icarus* , 270, 238-247. https://doi.org/10.1016/j.icarus.2016.02.013.

Blair, T.C. (2002). Cause of dominance by sheetflood vs. debris-flow processes on two adjoining alluvial fans, Death Valley, California.*Sedimentology* , 46, 1015-1028. https://doi.org/10.1046/j.1365-3091.1999.00261.x.

Bull, W.B. (1973). Geologic Factors Affecting Compaction of Deposits in a Land-Subsidence Area. *Geological Society of America Bulletin* , 84, 3783-3802. https://doi.org/10.1130/0016-7606(1973)84<3783:GFACOD>2.0.CO;2.

Bull, W.B. (1977). The alluvial-fan environment. *Progress in Physical Geography* , 1, 222-270. https://doi.org/10.1177/030913337700100202.

Chen, B., Gong, H.L., Li, X.J., Lei, K.C., Zhu, L., Gao, M.L & Zhou C.F. (2017). Characterization and causes of land subsidence in Beijing, China. *International Journal of Remote Sensing* , 38, 808-826. https://doi.org/10.1080/01431161.2016.1259674.

Chu, D., L., Z.Y., Bianba, C. & Liu, L.S. (2010). Land use dynamics in Lhasa area, Tibetan Plateau. *Journal of Geographical Sciences* , 20, 899-912. https://doi.org/10.1007/s11442-010-0819-0.

Dai, F., Lv, Z. & Liu, G. (2018). Assessing soil quality for sustainable cropland management based on factor analysis and fuzzy sets: a case study in the Lhasa River Valley, Tibetan Plateau.*Sustainability* , https://doi.org/10, 3477. 10.3390/su10103477.

Deng, Y.S., Shen X., Xia, D., Cai, C.F., Ding, S.W. &Wang, T.W. (2019). Soil erodibility and physicochemical properties of collapsing gully alluvial fans in southern China. *Pedosphere* , 29, https://doi.org/102-113. 10.1016/S1002-0160(15)60105-9.

Dickerson, R.P., Forman, A. & Liu, T. (2013). Co-development of alluvial fan surfaces and arid botanical communities, Stonewall Flat, Nevada, USA. *Earth Surface Processes & Landforms* , 38, https://doi.org/1083-1101. 10.1002/esp.3336.

Dorn, R.I. (1994). The role of climatic change in alluvial fan development geomorphology of desert environments. Chapman and Hall, London, pp. 593-615.

Fan, J., Wang, H.Y., Chen, D., Zhang, W.Z. & Wang, C.S. (2010). Discussion on sustainable urbanization in Tibet. *Chinese Geographical Science* , 20, 68-78. https://doi.org/10.1007/s11769-010-0258-y.

Gong, P., Liu H., Zhang, M.N., Li, C.C., Wang, J., Huang, H.B, . . . Song, L.C. (2019). Stable classification with limited sample: transferring a 30-m resolution sample set collected in 2015 to mapping 10-m resolution global land cover in 2017. *Science Bulletin* , 64, 370-373. https://doi.org/10.1016/j.scib.2019.03.002.

Jin, F.J., Wang, C.J., Li, X.W & Wang, J.E. (2010). China's regional transport dominance: Density, proximity, and accessibility,20, 295-309.*Journal of Geographical Sciences* , 20, 295-309. https://doi.org/10.1007/s11442-010-0295-6.

Khan, M.A., Haneef, M., Khan, A.S. & Tahirkheli, T. (2013). Debris-flow hazards on tributary junction fans, Chitral, Hindu Kush Range, northern Pakistan. *Journal of Asian Earth Sciences* , 62, https://doi.org/720-733. 10.1016/j.jseaes.2012.11.025.

Liang, W. & Hui, L. (2019). Quantitative evaluation of Tibet's resource and environmental carrying capacity. *Journal of Mountain Science* , 16, 1702-1714. 10.1007/s11629-018-5148-2.

Lin, X., Zhang, Y. L., Yao, Z. J., Gong, T. L., Wang, H., Chu, D., ... Zhang F. (2008). The trend on runoff variations in the Lhasa River Basin. *Journal of Geographical Sciences* , 1, 95-106. https://doi.org/10.1007/s11442-008-0095-4.

Ma, B., Zhang, J.Q., Shui, J.F., Zhao, C.J., Yang, L.H., Wang, H.L., ... Jiao J.Y. (2018). Report on Field Survey of Soil Erosion in Central and Eastern Tibet (in Chinese). *Bulletin of Soil and Water Conservation* , 38, 1-8. https: //10.13961/j.cnki.stbctb.2018.05.001.

Ma, D.T., Tu, J.J., Cui, P. & Lu, R.R. (2004). Approach to Mountain Hazards in Tibet, China. *Journal of Mountain Science* , 2, https://doi.org/143-154. 10.1007/BF02919336.

Maghsoudi, M., Simpson, I.A., Kourampas, N. & Nashli, H.F. (2014). Archaeological sediments from settlement mounds of the Sagzabad Cluster, central Iran: Human-induced deposition on an arid alluvial plain.*Quaternary International* , 324, 67-83. https://doi.org/10.1016/j.quaint.2013.10.057.

Mather, A.E., Stokes, M. & Whitfield, E. (2017). River terraces and alluvial fans: The case for an integrated Quaternary fluvial archive.*Quaternary Science Reviews* , 166, 74-90. https://doi.org/10.1016/j.quascirev.2016.09.022.

Mazzorana, B., Ghiandoni, E. & Picco, L. (2020). How do stream processes affect hazard exposure on alluvial fans? Insights from an experimental study. *Journal of Mountain Science* ,17, 753-772. https://doi.org/10.1007/s11629-019-5788-x.

Meinsen, J., Winsemann, J., Roskosch, J., Brandes, C., Frechen, M., Dultz, S., & Bottcher, J. (2014). Climate control on the evolution of Late Pleistocene alluvial-fan and aeolian sand-sheet systems in NW Germany. *Boreas* ,43, 42-66. https://doi.org/10.1111/bor.12021.

Okunishi, K. & Suwa, H. (2001). Assessment of debris-flow hazards of alluvial fans. *Natural Hazards* , 23, 259-269. https://doi.org/10.1023/A:1011162516211.

Rahaman, S. (2016). The formation and morphological characteristics of alluvial fan deposits in the Rangpo Basin Sikkim. *European Journal of Geography* , 7, 86-98.

Santangelo, N., Daunisiestadella, J., Crescenzo, G3, Di Donato V., Faillace, P., Martn-Fernndez, J. ... Scorpio, V. (2012). Topographic predictors of susceptibility to alluvial fan flooding, Southern Apennines. *Earth Surface Processes and Landforms* , 37, 803-817. https://doi.org/10.1002/esp.3197.

Sarp, G. (2015). Tectonic controls of the North Anatolian Fault System (NAFS) on the geomorphic evolution of the alluvial fans and fan catchments in Erzincan pull-apart basin; Turkey. *Journal of Asian Earth Sciences* , 98, 116-125. https://doi.org/10.1016/j.jseaes.2014.11.017.

Stock, J.D., Schmidt, K.M. & Miller, D.M. (2008). Controls on alluvial fan long-profiles. *Geological Society of America Bulletin* , 120, 619-640. 10.1130/B26208.1.

Telbisz, T., Imecs, Z., Mari, L. & Bottlik, Z., (2016). Changing human-environment interactions in medium mountains: the Apuseni Mts (Romania) as a case study. *Journal of Mountain Science* ,13, https://doi.org/1675-1687. 10.1007/s11629-015-3653-0.

Wang, G.J, Hu, X.M. & Garzanti, E. (2017). Early cretaceous topographic growth of the Lhasa Plano, Tibetan plateau: constraints from the Damxung conglomerate. *Journal of Geophysical Research: Solid Earth* ,122, 5748-5765. https://doi.org/10.1002/2017JB014278.

Tang W., Zhou T. C., Sun, Jian, S., Li Y., & Li W. P. (2017). Accelerated urban expansion in Lhasa city and the implications for sustainable development in a plateau city. *Sustainability* , 9,1-19. https://doi.org/10.3390/su9091499.

Wei, Y.L., Zhou, Z.H. & Liu, G.C. (2012). Physico-chemical properties and enzyme activities of the arable soils in Lhasa, Tibet, China.*Journal of Mountain Science* , 9, 558-569. https://doi.org/10.1007/s11629-012-2165-4.

Xu, X. (2013). Study on spatial distribution of surface water resources in Lhasa based on RS and GIS. *Applied Mechanics and Materials* , 368-370, 417-420. https://doi.org/10.4028/www.scientific.net/AMM.368-370.417.

Zhang, Y.L, Wang, C.L., Bai, W.Q., Wang, Z.F., Tu, L.L. & Yangjaen, D.G. (2010). Alpine wetlands in the Lhasa River Basin, China.*Journal of Geographical Sciences* , 20, 375-388. https://doi.org/10.1007/s11442-010-0375-7.

Zhuang, D. & Liu, J. (1997). Modeling of regional differentiation of land-use degree in China. *Chinese Geographical Science* , 7, 302-309. https://doi.org/10.1007/s11769-997-0002-4.

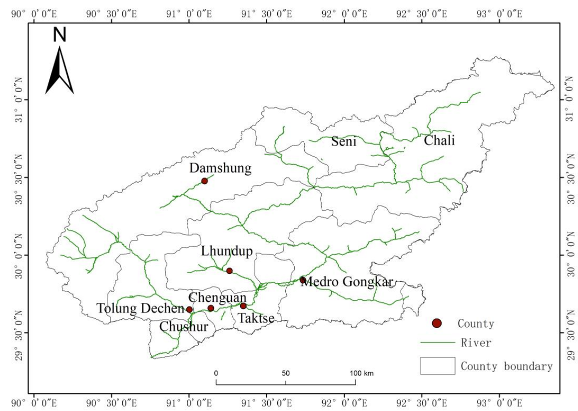

Fig.1 Location of the study area

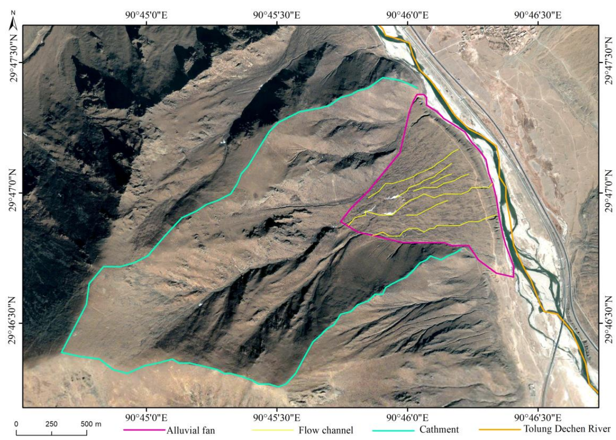

Fig.2 An alluvial fan located in LRB

Hosted file

`tables.docx` available at https://authorea.com/users/343137/articles/469786-the-distribution-and-land-use-characteristics-of-alluvial-fans-in-lhasa-river-basin-in-tibet

Hosted file

`figures.pdf` available at https://authorea.com/users/343137/articles/469786-the-distribution-and-land-use-characteristics-of-alluvial-fans-in-lhasa-river-basin-in-tibet