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ECOLOGICAL CONDITION AND ANIMAL CARRYING CAPACITY IN ANDEAN GRASSLANDS IN NATURAL POST CULTIVATION RESTORATION WITH LEPIDIUMMEYENII WALPERS

Raúl Yaranga*[1] & María Custodio[1]
[1] Universidad Nacional del Centro del Perú, Instituto de Investigación en Alta Montaña.Av. Mariscal Castilla N° 3909 - 4089, Huancayo, Perú

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ABSTRACT

The Andean grassland ecosystems experience a threat of desertification due to the change of use, in the central Andes of Peru, the crop of *Lepidiummeyenii*Walpers constitutes one of the causes, so the progress of the ecological condition (CE), the animal carrying capacity (CcA) and some edaphic characteristics, in plots of two, three, five, six and eight years post-harvest in seasons (rain and drought). Ten plots were evaluated by the linear transection method of intercept points. The analysis of the mixed general linear model and ANOVA were performed by Rstudio v.3.5.1 and CANOCO v.1.4 for multivariate analysis. Significant differences were found between native vegetation (VN) and revegetation plots (RV), between seasonal periods and RV time for $p \leq 0.05$. The VN CE was fair and in RV it ranged from poor to very poor. The CcA in VN was between 1.1 ± 0.64 sheep units per hectare per year (SU/ha/year) and in RV it oscillated between 0.2 ± 0.16 and 1.0 ± 0.44 SU/ha/year between two and eight years. Evident recovery was observed from the sixth year. Organic matter, nitrogen and time were the components that showed linear correspondence in the recovery of desirable species for livestock.

KEYWORDS: Andean pasture, ecological condition, animal carrying capacity, edaphic soil characteristics.

1. INTRODUCTION

Andean ecosystems provide important welfare services for humanity (Rolando et al., 2017) and the provision of habitat services to a diversity of wildlife species and livestock feed (Jurado et al., 2013; Lawley et al., 2016). Currently these ecosystems are affected in their physiological function, wealth, stability and the functioning of the plant community, by climate change by increasing the average temperature during the day and low temperature at night (Rashid et al., 2011; Martínez et al., 2014). This scenario affects the socioeconomic situation of rural populations and companies dedicated to andean livestock (Martin & Agüero, 2014). However, the change in use of pasture for agricultural purposes is considered to be the greatest threat that transforms ecosystems (Cao et al., 2017), generating visible spatial fragments where the habitat of many species of fauna diminishes or disappears (Schmidt, 2018), due to the total loss of native floristic diversity and the generation of a secondary succession process (Wiesmair et al., 2017). The pioneer species that initiate natural revegetation are not interested in feeding livestock (Squeo et al., 2006), so that livestock activity is affected until the emergence of desirable species for livestock considered an essential element of ecosystem service for pastoral communities in the medium and long term (Cárdenas, 2013).

In the central Andes of Peru, the change in the use of Andean grasslands by *Lepidium meyenii* Walpers crops is one of the causes with the greatest impact on floristic diversity and ecosystem services, which concerns rural populations and the entities involved, the process of slow and heterogeneous revegetation of the affected plots (Martínez, 2014, Cao et al., 2017). This process is limited by the weakness or lack of viability of the propagules of the available native vegetation, the microclimate and the socio-environmental conditions that have to do with the use of pasture by farmers (Derroire, 2016).

The areas of pasture and post-harvest pasture of *L. meyenii*, have been altered in their physical and chemical characteristics of the soil (Wiesmair et al., 2017), generated the decrease of organic mater (OM), pH, C and N of the soil (Crespo, 2011), so that the herbaceous communities that initiate revegetation are very different from the original ecosystem (Cárdenas, 2013), starting with invasive and temporary pasture species with little or no forage value for livestock (Cayuela, 2011) and over time they are gradually replaced by perennial species of higher forage value (Jurado et al., 2013; Schmidt, 2018). According to Caro et al. (2014) the puna turf disturbed by the removal of plant and soil for kitchen use, they recovered in four years, while the wetlands did it later. In this context, it is understood that the consequences of changing the use of vegetation cover in high andean grasslands affects the economic and ecological conditions in the medium and long terms (Enriquez et al., 2016).

The condition of the grassland is considered as a synonym of "condition of the vegetation", which for its description includes the analysis of some attributes such as: composition, structure and function of the plant community (Lawley et al., 2016) and its classification is based on in the evaluation of the state of health of the grassland, which is significantly influenced by the type of vegetation and the floristic richness mainly related to the desirable species for livestock, whose maintenance over time depends a lot on the way it is used by the farmers (Wiesmair et al., 2017). The qualification of the "ecological condition of the site" is determined according to a table established by the Universidad Nacional Agraria - La Molina, in five categories: excellent, good, fair, poor and very poor, according to the score ranges reached. In addition, this grassland condition also determines the animal carrying that must be applied to grazing, per hectare and per year. The table of the animal carrying capacity, differentiates the pet species: sheep and andean camelids (Condori, 2012).

Animal carrying capacity is estimated through the analysis of biophysical variables such as aerial pasture biomass, leaf index and aerial cover, also by measuring the vegetation index of standardized differences (Chávez et al., 2017). The carrying capacity for any herbivorous species is related to the range of forage offered by the grassland and the animal's food demand, expressed in the number of unit animal species that can graze on a hectare for one year (Flórez, 2017); In addition, this load capacity is closely related to primary production or phytomass production, which is estimated by making cuts of the available biomass in sample units. The carrying capacity obtained is considered as the maximum load of animals that can support a grazing area, without compromising its capacity for productive maintenance in terms of available biomass for livestock (Pulido, 2014).

In Peru it was found that the carrying capacity varies according to the associations: 1,156 SU ha/year in the association Festuchetum-Stipetum-Calamagrotisetum, 1,008 SU in the association Festuchetum-Muhlenbergietum and 1,027 SU in the association Festuchetum-Stipetum- Margiricarpetum; in pastures in poor to very poor condition, animal load capacity of 1,156, 1,008 and 1,027 SU ha / year was obtained (Cutimbo et al., 2016). In this context, the study evaluated the behavior of the ecological condition and carrying capacity of animals in affected pastures through the cultivation of LepidiummeyeniiWalpers with different time of revegetation.

2. MATERIAL AND METHODS

Study area

The study was carried out in the area "Lomo Largo", in the district of Pomacancha, province of Jauja and department of Junín, between the coordinates 11º33'37.50 "and 11º32'02.35" and between altitudes 3998 and 4262 meters. (Figure 1)

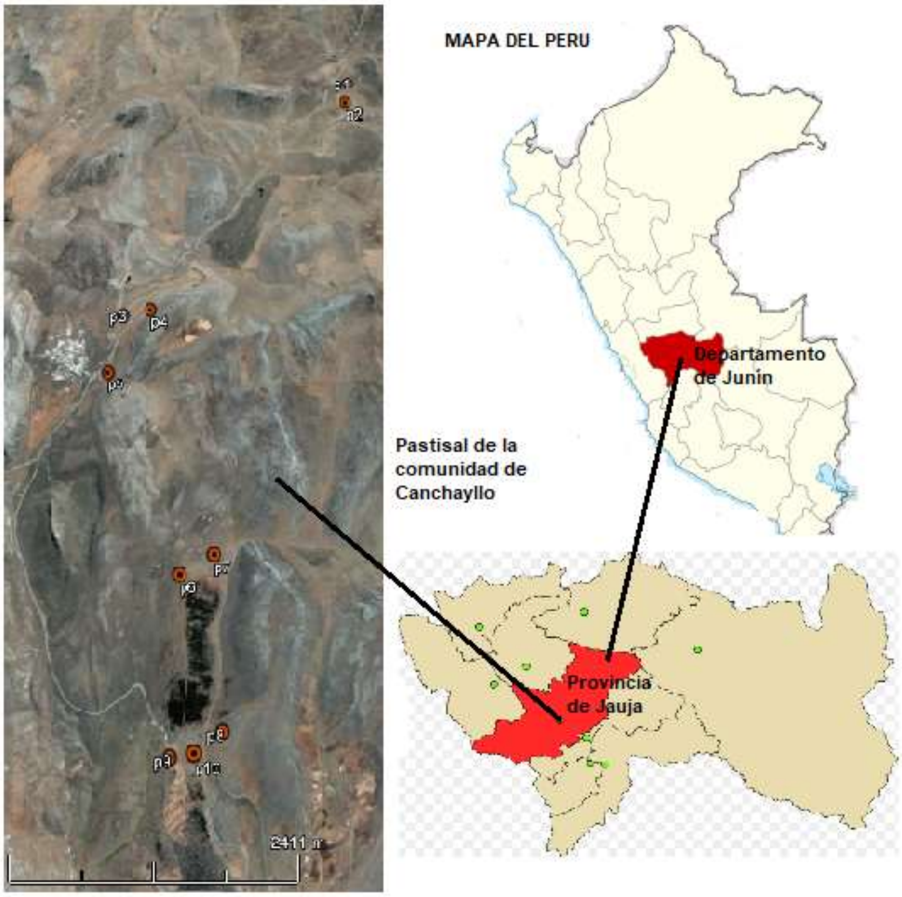

Figure 1. Location map of the study

The study area is comprised of a grassland cover with very little shrubby presence such as *Margiricarpus pinnatus* and *Chuquiraga spinosa* that are generally observed in the rocky outcrops and rocky outcrops. In these ecosystems, the communal and family livestock activity of the peasant community of Unión Paccha is developed. The soils of the study area are of colluvial origin, of very variable depth between 10 and 30 cm deep, clay loam texture and very variable pH between 4.5 and 7, with levels of organic matter equally variable between 3% and 10%. %. According to the classification of the "Soil Taxonomy" of the US corresponds to entisoles soils, to contain less than 30% of rock fragments (USDA, 2018) that alternates with other inceptisols and mollisols, for its altitudinal location greater than 3800 meters above sea level, of agrological quality medium to poor "P2, P3", which has limitations of soil "s", erosion "e" and climate "c", with variable slopes ranging from 10 to 30%.

According to data published by SENAMHI at the Ricran meteorological station, the rainfall characterizes two periods: one of rainfall between the months of October to April with a peak of greater rain between January to March with accumulated precipitation between 106 - 118 mm per month and another of low water that occurs between the months of May to September with minimum precipitation of 8.9 - 28 mm per month. The maximum temperature in the day fluctuates between 12.87 and 14.63 ° C, the minimum temperature at night and early morning fluctuates between 0.8 and 5.4 ° C

Obtaining data

The data collection was carried out in plots affected by *L. meyenii* crops, in a process of revegetation with two, three, five, six and eight years post-harvest, in 10 plots with different surfaces from 2.72 to 15.38 hectares of pastureland. We used the linear transection method of intercept points with 100 records for the agrostological evaluation (Cuesta & Becerra, 2012; Enriquez et al., 2016). It was recorded: the species of plant, mulch, moss, eroded soil and rock. In each plot, 4 transects were applied on the outer edge as native vegetation (VN) and 4

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transects inside the affected plot in revegetation processes (RV), in two seasonal periods: rainy (May 2017) and dry season (December 2017), accumulating 1600 records for each evaluated plot. The recognition of species was carried out by specialists from the Faculties of Zootechnics and from the Faculty of Forestry and Environmental Sciences (depository of the constructed herbarium) of the Universidad Nacional del Centro del Peru. Soil sampling was carried out using the technique recommended by MINAM for a square measuring 30 x 30 cm and 30 cm deep (Ministerio del Ambiente [MINAM], 2014), in a number of three samples per transect with approximately 1 kg of soil, finally a composite sample was obtained for VN and another for RV in each plot. The samples were analyzed in the laboratory of the Instituto Nacional de Investigacion Agropecuaria (INIA) Huancayo, in its components of: silt, clay, sand, pH, organic matter, nitrogen, phosphorus and potassium.

Analysis of data

The data obtained in each transect were organized in double entry matrix in Excel sheet, adopting the method followed by (Uchida et al., 2018): transect of origin and revegetation time in columns and species in rows for each seasonal period. The soil analysis data were organized considering the components in columns and the origin in rows. The agrostological sampling quality test was carried out using the accumulated curve test, recommended by (Kindt and Coe, 2011) using the RStudio software version 3.5.1. for the case of the ecological condition and animal carrying capacity, the data of desirable (D) and undesirable (PD) species for sheep has been extracted from the transect matrix. The calculation of the score for the ecological condition of the site was made using the Florez formula (2005).

$$C = 0.5D + 0.2D.DP + 0.2COB + 0.1V \quad (1)$$

For: C condition, D sum of desirable species, DP sum of undesirable species, COB soil cover and V vigor of the key species in%

The scores obtained were subjected to a mixed linear model analysis (Correa & Salazar, 2016, Banddera & Pérez, 2018) and ANOVA analysis through the use of RStudio version 3.5.2. The site condition score was related to the animal load capacity table, Florez (2005), which was processed with the same procedure above. The multivariate analysis of the relationship between grassland condition as response variable and soil characteristics, recovery time and seasonal periods, were analyzed by canonical correspondence (CCA), using CANOCO software version 4.5, taking into account the recommendations from Cayuela (2011); Arimoza et al. (2014) and Montanero (2018).

3. RESULTS

Pasture condition according to revegetation time and climatic period The pasture condition expresses the environmental health of the plant community, from the point of view of its livestock aptitude expressed in score. This score in the native vegetation varied between 48.19 and 54.02 corresponding to the rank of regular condition; in the plots with revegetation, the score varied between 13.51 and 37.11, corresponding to very poor and poor conditions (Table 1).

Animal load capacity

The animal load capacity (CcA) expresses the number of sheep units that can graze on one hectare during one year (SU/ha/year), without compromising the current pasture condition (Figure 2a). The CcA in the native vegetation varied between 0.8 and 1.3 SU/ha/year and in the revegetation plots from 0.2 to 1.0 (Figure 2b). In both cases, the highest CcA of the pasture occurred during the rainy season compared to the low season.

Table 1. Scoring and classification of pasture condition according to recovery time and climatic period

	VN rain		VN low water		RV rain		RVlow water	
	PP	CE	PP	CE	PP	CE	PP	CE
2 years	53.12	R	47.6	R	30.80	P	13.51	MP
3 years	52.35	R	44.48	R	35.15	P	17.36	P
5 years	50.93	R	52.09	R	41.00	P	17.36	P
6 years	54.02	R	49.66	R	37.11	R	24.33	P
8 years	48.19	R	49.66	R	37.11	R	37.58	R

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Caption: VN native vegetation, RV plot in revegetation; MP very poor, P poor, R regular; PP condition score, EC ecological condition of the grassland

A significant difference was found between VN and RV in the analysis of ecological condition residues and animal load capacity. The animal load capacity for sheep in RV that is corresponding to the ecological condition, was found significant difference between seasonal periods with p = 0.00011 (Figure 2c) and between revegetation time with p = 0.00018 (figure 1d) in which the plots of six and eight years are superior (Figure 2d).

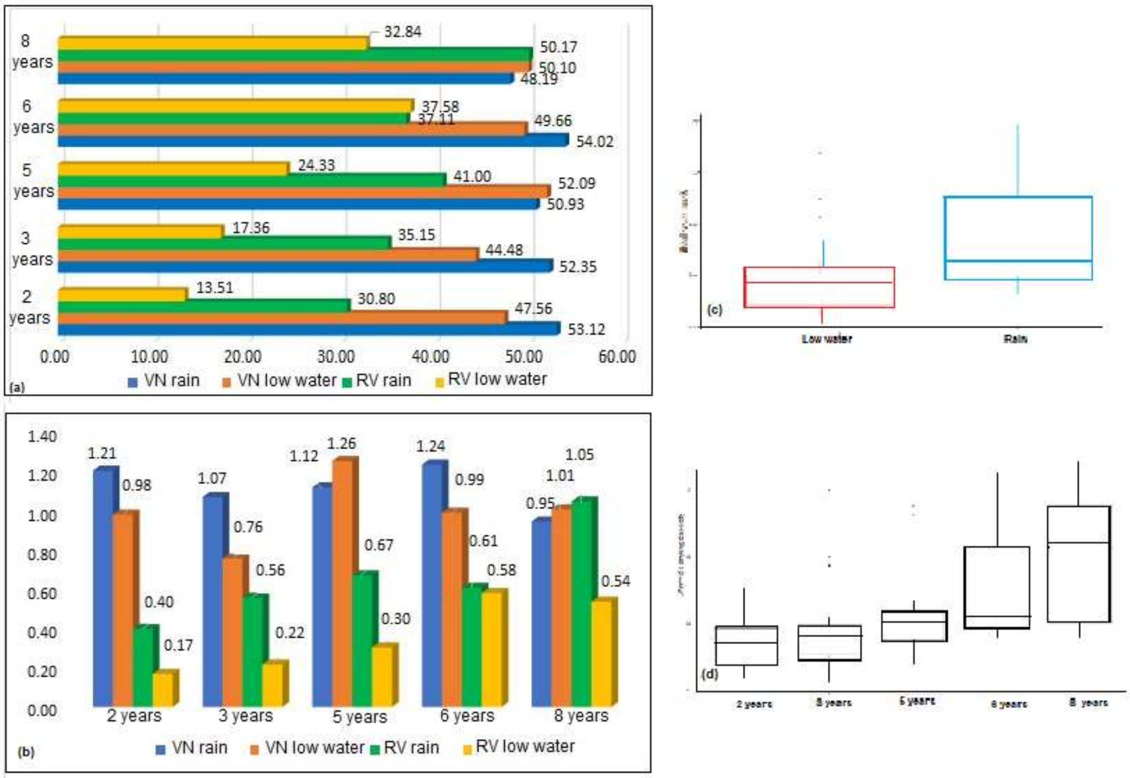

Figure 2. (a) Ecological pasture condition score, (b) animal carrying capacity for sheep, according to (c) seasonal period and (d) revegetation time.

Canonical correspondence between pasture condition and animal carrying capacity with soil characteristics, revegetation time and seasonal period

The pasture condition and the animal carrying capacity have been differentiated according to the seasonal period (Figure 3). During the dry season, they were related to organic matter, nitrogen, clay, revegetation time and P; while, in the seasonal period of rain they showed correspondence with pH and silt. This difference could be based on the presence of temporary species that were present only in the rainy season.

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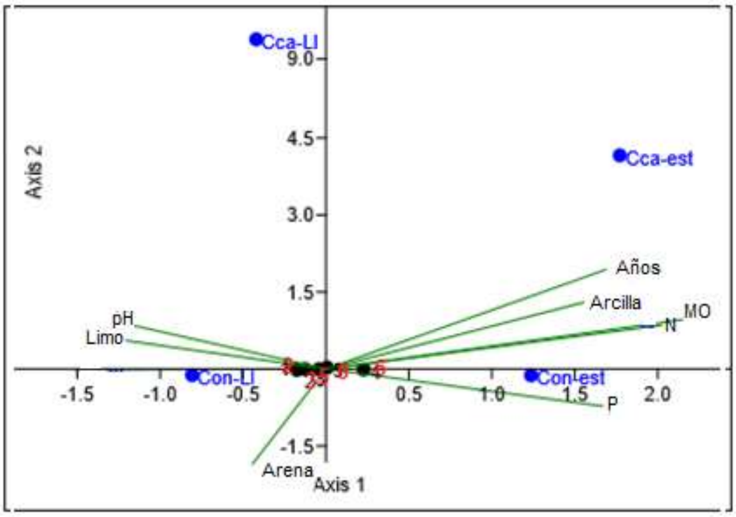

Figure 3

Canonical correlation between pasture condition and animal loading capacity of revegetation plots with soil characteristics, according to abandonment time and seasonal period. (Cca-ll) carrying capacity in rainy season, (Cca-est) carrying capacity in the dry season; (Cond-ll) condition of grassland in rainy season, (Cond-est) condition of pasture in dry season).

4. DISCUSSION

The ecological condition of the pasture is strongly related to the richness and structure of the pasture (Florez, 2005, Lawley et al., 2016). This conception is based on the criterion that each type of livestock has preference to certain species of natural grass, so the ecological condition of the pasture is specific for each type of livestock (Florez, 2005). The variation of the floristic composition plus the biomass production of the desirable species for the cattle, determine the grazing support capacity (Wiesmair et al., 2017). The pasture condition score reached in the native vegetation for sheep, are considered as intermediate values and the established ranges place them in the regular condition (41 to 60 points).

The animal carrying capacity obtained indicates that the areas included in the study are degraded due to overuse or overgrazing (Florez, 2005), which is a very common practice in andean grassland ecosystems. The report of some studies on the animal carrying capacity, indicate that this one surpasses in more than two times to the bearableness of the grazing areas, mainly in peasant communities (Villa-Herrera et al., 2014). In the revegetation plots, the pasture condition score places them in the poor condition (21 to 40 points) and very poor (<20 points) (Florez, 2005), as a consequence of the revegetation process that begins with few invasive species without forage value for livestock (Villa-Herrera et al., 2014); but that, the score increases as the revegetation time advances with a greater number of desirable species for cattle (Cutimbo et al., 2016), significantly from the sixth year in our case. The pasture animal capacity is the central point of economic valuation of pasture (Lawley et al., 2016), and the essential economic foundation for Andean settlers (Heringer & Carvalho, 2002; Hernández et al., 2009).

The result obtained is very close to that obtained in pastures of Puno of 1,156, 1,008 and 1,027 in different agrostological associations (Cutimbo et al., 2016), which suggests that these are the average levels of the andean grasslands. While they are higher than those obtained at the páramo level in Ecuador from 0.17 to 0.79 SU/ha per year, under family management conditions. The animal carrying capacity in the plots with revegetation begins from zero due to the total loss of the floristic diversity, whose revegetation is visible at two years with the presence of pioneer species of secondary succession of temporary character and without fodder value for the cattle (Wiesmair et al., 2017). The carrying capacity obtained, 0.2 SU/ha per year, means that 5 hectares of grassland in these conditions is barely enough for the grazing of a female sheep of 30 kg of live weight during a year, without it being able to put the pasture at risk of deterioration . The important presence of desirable species for cattle occurred after five years, without the possibility of reaching the same original condition (Vargas, 2011, Fiallos et al., 2015). This situation has caused not only the loss of biodiversity and environmental services, but also the economic loss of the rural population dedicated to Andean livestock (Martínez, 2014, Caro et al., 2014), directly affecting livestock families and not to those who used the pastures for the commercial crop of *L. meyenii* (Pulido, 2014, Hofstede et al., 2014, McGinlay et al., 2017), which demonstrates an ecological and social injustice.

The multivariate analysis by canonical correspondence of the carrying capacity, with the explanatory environmental variables: soil characteristics, climatic period and time of revegetation (Montanero, 2015, Pérez et al., 2017), are different between seasonal periods, as a consequence of the climatic limits mainly of precipitation and temperature to which the floristic diversity of pastures adapted to mountain ecosystems is adapted (Florez, 2005, Squeo et al., 2006). The most evident relationship of the pasture condition and animal carrying capacity in the dry period with the OM, N, P, is supported by the abundance of desirable perennial species that are significant at six and eight years (Martín et al., 2011), which was not evident in the rainy season due to the presence of temporary species that are not very demanding in these nutrients, and have a very short life cycle (Ge et al., 2017).

5. CONCLUSIONS

The implementation of agricultural activities in grassland ecosystems severely alters their usefulness in livestock feeding, and this has a direct impact on the economy of livestock families, for at least five years post-harvest of *L. meyenii*. The plots with change of use up to eight years of revegetation have not shown evidence of complete recovery, neither in the resemblance to the original floristic composition, nor in the animal carrying capacity, for the affectation to the edaphic and microbiological characteristics of the soil.

6. RECOGNITION

To the peasant community of Union Paccha, for the facilities provided for carrying out the field work, to SERFOR for authorizing the research work with wild plants.

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