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Forage oat (*Avena sativa* L.) an important transitory crop for feeding animals in Peruvian highlands

Avena forrajera (*Avena sativa* L.) un cultivo transitorio importante para la alimentación animal en la sierra peruana

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Abstract

The main objective of this research was to analyze different institutional data bases related to harvested area, yield and production of forage oat crops, from 2017 to 2022, at regional and country level. For this purpose, statistical data information was taken from 14 regions where oat is cultivated in Peru. The current research had a non-experimental quantitative approach, by using the data provided by the Instituto Nacional de Estadística e Informática (INEI) and the Ministerio de Desarrollo Agrario y Riego (MIDAGRI). Collected data was organized in a group of spreadsheet of Excel 365, after that the same software was used for data processing and analysis. Results showed that oats had the greater sown area among transitory crops in the country. During the analyzed data period, Puno region increased its forage oat area harvested by 16.31 % (68 040 ha in 2017 to 79 139 ha in 2022) and obtained the highest mean yield (28.32 $t.ha^{-1}$) and production (2 138 637.62 t) that the other regions and it mainly produced 80.12 % of country production (2 669 276.67 t) of fresh forage.

Keywords: *forage oat (Avena sativa L.); highlands; indicators; harvested area; yields; production.*

Resumen

El objetivo principal de esta investigación fue analizar diferentes bases de datos institucionales relacionadas con el área cosechada, rendimiento y producción de los cultivos de avena forrajera, del 2017 al 2022, a nivel regional y nacional. Para ello, se tomó información de datos estadísticos de 14 regiones donde se cultiva avena en el Perú. La presente investigación tuvo un enfoque cuantitativo no experimental, al utilizar los datos proporcionados por el Instituto Nacional de Estadística e Informática (INEI) y el Ministerio de Desarrollo Agrario y Riego (MIDAGRI). Los datos recolectados fueron organizados en un grupo de hojas de cálculo de Excel 365, posteriormente se utilizó el mismo software para el procesamiento y análisis de los datos. Los resultados mostraron que la avena tuvo la mayor superficie sembrada entre los cultivos transitorios del país. Durante el periodo de datos analizados, la región Puno incrementó su área cosechada de avena forrajera en 16,31 % (68 040 ha en 2017 a 79 139 ha en 2022) y obtuvo el mayor rendimiento medio (28,32 t.ha-1) y producción (2 138 637,62 t) que las demás regiones y produjo principalmente el 80,12 % de la producción del país (2 669 276,67 t) de forraje fresco.

Palabras clave*: avena forrajera (Avena sativa L.); altiplano; indicadores; superficie cosechada; rendimientos; producción.*

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Introduction

Green forage constitutes a cheap and valuable source of energy (Kanwal et al., 2022), which covers the nutritional requirements demanded by the various breeds. In this context, *Avena sativa* L. constitutes an essential food source for cattle and other species (Gutiérrez et al., 2021), representing a good option in the face of reduced forage supply (Campuzano et al., 2020), being also a sustainable alternative for livestock production (Torres et al., 2020).

Forage oat (*Avena sativa* L.) is an annual crop classified into the Poaceae family, native to Western Europe. It.has a vertical growth from a basal rosette. Individual plant produces numerous stems which can reach more than 150 centimeters in height (Martínez, 2020). As a temporal cropping, oat adapts very well to the different environmental conditions at Peruvian highlands where it is grown basically for green forage for feeding grazing animals, hay forage, silage, grain and balanced feed (Espitia et al., 2012; Mamani & Cotacallapa, 2018).

In Peru, forage oat is sown along 14 of the 26 regions in the country lands (Ministerio de Desarrollo Agrario y Riego [MIDAGRI], 2020), especially during the dry season or when rainy season is delayed and animals demand for food. According to Alejo et al. (2020), the low water availability determines a reduction of primary production of forage oat yields. For this reason, cropping oat is a good alternative resource to fill the food demand for dairy cattle in the highlands (Mamani & Cotacallapa, 2018).

For livestock, it has a good nutritional value: 66.48 % ± 1.59 % of digestible dry matter, 2.63 % ± 0.26 % of CMS, 136.39 ± 15.85 of forage relative value and 1.33 cal.kg^{-1} ± 0.04 cal.kg^{-1} DM of net lactation energy. Its chemical composition is 27.95 % ± 1.58 % of dry matter, 5.6 ± 0.67 % of total ashe, 8.67 % ± 0.64 % of crude protein, 7.99 % ± 0.70 % of ethereal extact, 30.77 % ± 3.33 % of non fibre carbohydrates, 46.97 % ± 3.59 % of NDF, 28.78 % ± 1.94 % of ADF and 18.19 % ± 2.56 % of hemicellulose (Mamani & Cotacallapa, 2018).

In the central Peruvian highlands, forage oat is conserved as haymaking to obtain feed for livestock during the dry season because of the good biomass yield and nutritional content (Noli et al., 2017). This is because of water scarcity affects the plant development of several forage species used as fresh fodder by small farmers in the Andes of South America (Contreras et al., 2020). Forage oat yields vary, due to location, genotype or variety, climatic factors, soil fertility, size of agricultural units and crop management (Sánchez et al., 2014).

The genotype-environment interaction greatly influences the yield and good quality of forage oat. Forage oat as a crop shows the potential to produce high dry matter production and high nutritional quality (Espitia et al., 2012). Fodder oats is a crop of adaptability to different environmental conditions (2500-4200 m.a.s.l). It can be established in soils with a light to medium texture (loam to silt loam) to slightly sandy (sandy loam); without drainage problems with a pH slightly acidic to neutral (5-7) (Arias et al., 2021), and oat plants requires temperatures from 12 ºC to 16 ºC to develop its potential yield (Instituto Nacional de Innovación Agraria [INIA], 2007; Espitia et al., 2 12), however, temperatures higher than 16 °C reduce the production of fresh forage (FF) and, therefore, the dry matter (DM) yields.

Data base to analyse the current paper was elaborated from reports of the Instituto Nacional de Estadística e Informática (INEI), a governmental official office of Peru which it is in charge of producing and sharing the country´s official statistical information with other organizations and institutions. The most important statistical report on the agricultural sector is published as the Agricultural Census. Cropping oat data was obtained as basic data information on agricultural activities for each Peruvian region. This information is used to propose agricultural policies and development plans and supporting future statistical research in the agricultural sector (Instituto Nacional de Estadística e Informática [INEI], 2021).

Another data reports were taken from the Dirección de Estadística Agraria (DEA) within the Dirección General de Seguimiento y Evaluación de Políticas (DGESEP) at Ministerio de Desarrollo Agrario y Riego (MIDAGRI). They report a Monthly Bulletin named "El Agro en Cifras". This document contains economic indicators related to agricultural activities to follow a monthly evolution which it allows to monitor and analyse the activities and products of the agricultural sector (MIDAGRI, 2020).

The importance of collecting agricultural data is to understand the trends in forage oat for animal feed in Peru led to analyse basic information to identify technical indicators from 2017 to 2020. This study highlights the importance of having an overview of past and current situation to establish technical proposals to improve livestock production systems in Peruvian highlands zone.

Materials and methods

The research was planned as a non-experimental quantitative approach and was focused on the systematization and numerical analysis of data obtained and its interpretation. Collecting data started from INEI´s database inside their virtual reports and interactive MS Excel Spreadsheets. Also, we used databank from the Ministerio de Desarrollo Agrario y Riego. The indicators analysed were the harvested area, the yield per hectare and the oat production. Gómez (2018), indicates that statistical information presents existing data previously collected by a researcher or institution and that, in non-experimental research, reliable sources of information must be used to develop adequate research.

Informatic equipment used were two personal computers with Windows 10 operating with system licenses; Microsoft Word and Excel 365 programs. Also, some stationery such as paper, note formats, pens and USB.

The annual production of oat was determined as follows:

Production (t) = Harvested area (ha) x Yield ($t.ha^{-1}$)

- Calculation of the per cent of variation (VAR) of the harvested area, yield and production, the following formula was used: M = (∑ 2017 to 2022)/6
- Calculation of the % related (% R) to country harvested area or DM production by region, the following formula was used: % R = (M * 100)/MC. Where: MC = mean country
- Calculation of the yield or production variation (V) related to 2017, the following formula was used: V ($t.ha^{-1}$) (year 2022) = (YP (year 2022) - YP (year 2017))

Where:

V ($t.ha^{-1}$) (year 2022) = Variation in tonnes of the oats in the current year (2022) compared to the reference year (2017).

YP (year 2022) = Value of yield or production oats of the current year or under study.

YP (year 2017) = Value of yield or production the oats of the reference year.

Results and Discussion

Harvested area

Oat is sown in the coldest regions in Peru, especially in valleys where other temporal and perennial forage crops are used for feeding stocking ruminants. Considering a group of fourteen regions, registered oat as an important crop in Puno where animal production becomes one of the main activities. Thus, Puno is the first region with the largest harvested area (75 070.5 ha ± 3 759.84 ha; 71.56 %). The second region is Cusco (11 701.34 ± 2 937.99 ha; 11.15 %) followed by other two regions, Ayacucho (6 674.33 ha ± 1167.83 ha; 6.36 %) and Junín (5 385.49 ha ± 266.05 ha; 5.13 %). Then, the four regions accumulated 94.2 % of lands sown with oat since 2017 (Table 1).

Yield per hectare

Forage oat can potentially produce between 40 $t.ha^{-1}$ to 60 $t.ha^{-1}$ in 150 days from October to March (Noli et al, 2017). Actually, mean yields of forage oat vary in a range of 3.0 $t.ha^{-1}$ ± 4.69 $t.ha^{-1}$ to 29.32 $t.ha^{-1}$ ± 5.31 $t.ha^{-1}$, where Puno produces 9.44 times more mean fresh matter respect of the lowest yield (Lima). Ayacucho

Table 1. Harvested area (ha) of forage oat at the regional and national levels

Region	2017	2018	2019	2020	2021	2022	Mean harvested area by region	SD among years by region	Yield variation related to 2017 (t ha^{-1})	% Related to country harvested
Puno	68 040	75 165	75 010	76 086	76 983	79 139	75 070.50	3 759.84	11099	71.56
Cusco	8 662	7 858	13 608	11 685	12 962	15 433	11 701.34	2 937.99	6771	11.15
Ayacucho	5 318	5 774	7 562	6 328	6 586	8 478	6 674.33	1 167.83	3160	6.36
Junín	4 929	5 405	5 345	5 335	5 676	5 623	5 385.49	266.05	694	5.13
Huánuco	982	847	1 027	1 275	1 310	1 261	1 116.83	190.85	280	1.06
La Libertad	1 184	1 553	1 417	1 533	1 542	1 189	1 402.75	174.71	6	1.34
Huancavelica	834	485	1 112	1 517	1 778	1 066	1 132.00	464.27	232	1.08
Cajamarca	666	852	591	775	1 260	988	855.33	242.30	322	0.82
Apurímac	937	1 351	794	776	864	636	893.00	245.90	-301	0.85
Arequipa	434	347	350	471	516	540	443.00	81.81	106	0.42
Pasco	252	238	197	129	138	175	188.17	50.65	-77	0.18
Moquegua	14	37	22	14	35	35	26.17	10.83	21	0.02
Tacna	6	4	32	0	0	2	7.33	12.31	-4	0.01
Lima	0	0	17	3	0	0	3.33	6.80	0	0.00
Country	92 257	99 916	107 084	105 924	109 650	114 565	104 899.57			100.00

Source: Direcciones Regionales de Agricultura MIDAGRI-DEA

(19.44 t.ha^{-1} ± 2.24 t ha^{-1}), Junín (17.63 t.ha^{-1} ± 1.40 t ha^{-1}) and Huancavelica (15.75 t.ha^{-1} ± 3.10 t ha^{-1}) regions produce the best yields, 6.48, 5.88 and 5.25 times higher yields compared to Lima´s (Table 2). However, Arequipa has had a reduction of 1.92 t.ha^{-1}mean yield every year from 2017 to 2022.

The wide range of variation in the forage oat yields per hectare in the different regions may be due to use of different plant variety or cultivar, soil fertility and climate conditions, the farm size or the crop management according to Sánchez et al. (2014). Because the difference of soil origin and natural soil fertility and fertilization programmes these produce differences yield and production responses. Also, those characters related to climate conditions reflect their production and yields on oat varieties. Forage oats can produce up to very high attitude (4000 to 4200 m.a.s.l), but with very low production because of colder air temperatures (Contreras et al., 2020).

Green forage production (GF)

Green forage is compulsory necessary for feeding animals during the whole year, especially in winter when shortage of fodder dramatically decline. The, forage oat become an important temporary feed for animals to supply green forage as conservation (hay or silage) products. In Peru, oat cultivation showed increments and reductions in green production according to the region among 2017 to 2022 (MIDAGRI, 2020; MIDAGRI, 2022). The highest green forage production of oat at country level was obtained in 2022, where Puno produced 80.12 % of the annual country production, after Cusco (7.828 %), Ayacucho (4.909 %) and Junín (3.567 %) (Table 3). The ten other regions had the lowest green production (3.576 %, all together). In 2022, among these ten regions Apurímac, Pasco, and Tacna decreased the green production, but Huánuco, Huancavelica, Cajamarca and Arequipa regions increased their oat green production compared to 2017.

Harvested area, mean yield and total production regional

There are 13 regions where forage oat is harvested with different area, yield and production (INEI, 2021). Among these, Puno has the highest harvested area (79 139 ha, 82.265 %), mean regional yield (37.66 t.ha^{-1}) and total production (2 979 983 t, 82.265 %) by region of total country.

Table 2. Yield of fresh forage (t.ha^{-1}) of forage oats at the regional level

Region	2017	2018	2019	2020	2021	2022	Mean yield by region	SD among years by region	Yield variation related to 2017 (t ha^{-1})	Rate related to the lowest yield
Puno	23.75	23.86	25.83	27.96	30.89	37.66	28.32	5.31	13.90	9.44
Ayacucho	16.60	19.99	17.56	20.40	19.15	22.94	19.44	2.24	6.33	6.48
Junín	16.18	17.07	16.96	16.89	18.89	19.82	17.63	1.40	3.64	5.88
Huancavelica	14.57	14.10	12.44	14.18	20.30	18.90	15.75	3.10	4.33	5.25
Arequipa	19.77	16.63	16.37	16.09	15.82	17.85	17.09	1.49	-1.92	5.70
Huánuco	14.38	16.69	17.09	16.00	16.18	16.19	16.09	0.93	1.81	5.36
Cusco	17.19	16.66	19.08	21.99	16.09	15.85	17.81	2.35	-1.34	5.94
Cajamarca	18.85	19.47	20.66	17.58	15.78	15.42	17.96	2.08	-3.43	5.99
Pasco	12.63	13.35	8.98	11.63	10.72	15.13	12.07	2.14	2.50	4.02
La Libertad	13.33	14.36	14.64	14.83	14.64	13.28	14.18	0.69	-0.05	4.73
Apurímac	14.43	19.73	16.37	13.85	11.49	11.98	14.64	3.05	-2.45	4.88
Moquegua	16.18	16.71	16.00	16.53	15.63	10.72	15.29	2.27	-5.46	5.10
Tacna	12.00	12.00	11.34	0.00	0.00	6.00	6.89	5.79	-6.00	2.30
Lima	0.00	0.00	10.00	8.00	0.00	0.00	3.00	4.69	0.00	1.00

Source: Direcciones Regionales de Agricultura MIDAGRI-DEA

Cusco has the second place but much lower than Puno (Table 4).

Dry matter production (DM)

Dry matter yield is a directly factor related to green forage for feeding animals. Dry matter varies according to variety, soil fertility and fertilization doses, and altitude. Forage oat has, generally, dry matter in a range of 25 % to 27 % (INIA, 2007). Dry matter is used to calculate the forage intake demand by animals which it is expressed as dry matter (DM) per 100 kg body animal weight so it is essential to determine it. Based on the green forage (FF) production, shown in Table 3, the annual dry matter production (Table 5) was calculated by region and country level considering 27 % from green oat production.

The yields obtained from DM expressed a wide range of data, which coincided with

Table 3. Total, green oat forage production (t) by region from 2017 to 2022

Region	2017	2018	2019	2020	2021	2022	Mean production by region	SD among years by region	Production variation related to 2017 (t ha^{-1})	% Mean by region from country production
Puno	1 616 017	1 793 273	1 937 349	2 127 098	2 378 106	2 979 983	2 138 637.62	489 544.06	1 363 966.30	80.120
Cusco	148 885	130 884	259 675	256 960	212 665	244 645	208 952.25	56 334.68	95 760.50	7.828
Ayacucho	88 299	115 407	132 790	129 062	126 146	194 464	131 027.92	34 999.22	106 165.00	4.909
Junín	79 722	92 255	90 657	90 074	107191	111440	95 223.39	11 854.73	31 718.14	3.567
Huánuco	14 116	14 137	17 551	20 397	21 184	20 416	17 966.83	3 222.54	6 300.00	0.673
Huancavelica	12 153	6 840	13 834	21 509	36 085	20 144	18 427.54	10 187.97	7 991.40	0.690
La Libertad	15 778	22 289	20 744	22 725	22 570	15 791	19 982.87	3 327.67	12.50	0.749
Cajamarca	12 555	16 589	12 211	13 625	19 885	15 236	15 016.77	2 901.09	2 680.59	0.563
Arequipa	8 581	5 771	5 730	7 577	8 162	9 640	7 576.94	1 567.20	1 058.95	0.284
Apurímac	13 513	26 658	12 999	10 746	10 333	7 619	13 644.50	6 714.90	-5 893.69	0.511
Pasco	3 182	3 177	1 769	1 501	1 479	2 648	2 292.68	807.88	-534.19	0.086
Moquegua	227	618	352	231	672	375	412.52	190.84	148.61	0.015
Tacna	72	48	363	0	0	12	82.50	140.40	-60.00	0.003
Lima	0	0	170	24	0	0	32.33	68.12	0.00	0.001
Country	2 013 099	2 227 946	2 506 193	2 701 529	2 944 479	3 622 413	2 669 276.67		1 609 314.11	100.00

Source: Direcciones Regionales de Agricultura MIDAGRI-DEA

Table 4. Harvested area, mean yield and total production by region of forage oat as fresh matter at 2022

Region	Harvested area (ha)	% of total country harvested	Mean regional yield (t ha^{-1})	Rate related to the lowest regional yield	Total production by region (t)	% of region against total country production
Puno	79 139	69.08	37.66	6.276	2 979 983	82.265
Cusco	15 433	13.47	19.82	3.303	244 645	6.754
Ayacucho	8 478	7.40	18.90	3.150	194 464	5.368
Junín	5 623	4.91	15.85	2.642	111440	3.076
Huánuco	1 261	1.10	13.28	2.214	20 416	0.564
La Libertad	1 189	1.04	17.85	2.975	15 791	0.436
Huancavelica	1 066	0.93	22.94	3.823	20 144	0.556
Cajamarca	988	0.86	15.42	2.570	15 236	0.421
Apurímac	636	0.56	11.98	1.997	7 619	0.210
Arequipa	540	0.47	16.19	2.698	9 640	0.266
Pasco	175	0.15	15.13	2.522	2 648	0.073
Moquegua	35	0.03	10.72	1.787	375	0.010
Tacna	2	0.00	6.00	1.000	12	0.000
Country	114 565	100.00			3 622 413	100.00

Source: Direcciones Regionales de Agricultura MIDAGRI-DEA

Sánchez et al. (2014) results, who indicated that dry matter yield varies according to location, variety, soil conditions and climatic factors. Similarly, Achleitner et al. (2008) and Ramírez et al. (2013), confirmed that DM yield is affected by the cutting numbers in different phenological phases of the oat plant. As cutting time becomes closer to physiological maturity, DM yield is expected to increase linearly.

Animal feeding

Simulating data, DM produced by forage oat along the 6-year period, and considering the animal demand per day as 2.1 and 2.5 kg DM per 100 kg body weight under silage and hay, respectively, the number of bovines of 450 kg body weight are showed in table 6. In one single day, a range of 45,295 to 61,845 animals could graze fed the DM produced, with silage would be a range of 64,707 to 88,350 and hay in a range of 54,375 to 74,243 animals.

Table 5. Dry matter production (t) of forage oat by region

Region	2017	2018	2019	2020	2021	2022	Mean annual production by region	% mean from country DM production	SD among years by region
Puno	436 324	484 184	523 084	574 316	642 089	804 595	577 432	80.120	132 176.90
Cusco	40 199	35 339	70 112	69 379	57 420	66 054	56 417	7.828	15 210.36
Ayacucho	23 841	31 160	35 853	34 847	34 059	52 505	35 378	4.909	9 449.79
Junín	21 525	24 909	24 477	24 320	28 942	30 089	25 710	3.567	3 200.78
Huánuco	3 811	3 817	4 739	5 507	5 720	5 512	4 851	0.673	870.09
Huancavelica	3 281	1 847	3 735	5 807	9 743	5 439	4 975	0.690	2 750.75
La Libertad	4 260	6 018	5 601	6 136	6 094	4 263	5 395	0.749	898.47
Cajamarca	3 390	4 479	3 297	3 679	5 369	4 114	4 055	0.563	783.30
Arequipa	2 317	1 558	1 547	2 046	2 204	2 603	2 046	0.284	423.14
Apurímac	3 648	7 198	3 510	2 901	2 790	2 057	3 684	0.511	1 813.02
Pasco	859	858	478	405	399	715	619	0.086	218.13
Moquegua	61	167	95	62	181	101	111	0.015	51.53
Tacna	19	13	98	0	0	3	22	0.003	37.91
Lima	0	0	46	6	0	0	9	0.001	18.39
Country	543 537	601 545	676 672	729 413	795 009	978 052	720 705	100.000	

Source: Direcciones Regionales de Agricultura MIDAGRI-DEA DM = dry matter

Conclusions

In Peru, fodder oats have achieved great importance in livestock farming areas, which is reflected in the area harvested in recent years. Among 26 regions of the country, 14 regions had area harvested with fodder oats. From 2017 to 2022, Puno and Cusco were the regions that increased the harvested area and, had the highest production and yield throughout the country. Fodder oats are the main transitory fodder crop used for animal feed in the highlands; consequently, it is an alternative feed for animals during the dry season, when there is a shortage of pasture production.

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Table 6. Simulation of total number of bovines which be fed by total country production of dry matter of forage oat during 120 days of dry season every year from 2017 to 2022

Years	Country DM production (t)	Silage		Hay	
		Consumption DM dry season (t/bovino)*	Number of bovines	Consumption DM dry season (t/bovino)**	Number of bovines
2017	543 537	1.134	479 309	1.350	402 620
2018	601 545	1.134	530 463	1.350	445 589
2019	676 672	1.134	596 713	1.350	501 239
2020	729 413	1.134	643 221	1.350	540 306
2021	795 009	1.134	701 066	1.350	588 896
2022	978 052	1.134	862 479	1.350	724 483

* 450 kg PV x 2.1% x 120 days ** 450 kg PV x 2.5% x 120 days

Author contributions

Elaboration and execution, development of methodology, conception and design; editing of articles and supervision of the study have involved all authors.

Conflicts of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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