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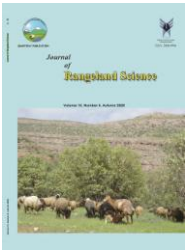

Research and Full Length Article:

A Simulation Model for Estimating Herbage Standing Crop and Grazing Capacity in Sar Ali-Abad Summer Rangelands of Golestan Province, Iran

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Received on: 25/03/2019
Accepted on: 23/06/2020

Abstract. To find an accurate and rapid method of estimating herbage crop, Double Sampling (DS), Comparative Yield (CY), and clipping and weighing (CW) methods were applied to a summer rangeland in North-eastern Alborz Mountains, Iran. The method was called SMFY (Simulation Model of Forage Yield) to emphasize the statistical aspects of simulated model. In representative stands five 1-m^2 reference plots were chosen to represent the ranges of standing crop. Using a systematic-random design, 180 1-m^2 plots were ranked against the reference plots for CY, visually estimated for DS, and subsequently, all of them were Clipped and Weighed (CW). After clipping and weighing 5 reference plots with 6 replications for CY and estimating and clipping 37 plots for DS, regression lines were plotted between the estimated, ranked, and clipped plots. This study was conducted during 2011-13. There was high correlation (0.90-0.99) for DS and CY, so the estimated and ranked data were corrected based on the regression equations. There were strong linear relationships between the corrected and clipped data for the DS and CY methods which confirmed the suitability of both methods against the CW, so all of 180 estimated plots were corrected and were compared by ANOVA. The non-significant F for CY, DS, and CW confirmed the high efficiency of DS and CY, so based on the estimated production, grazing capacity of study area was calculated. Preferring one of these methods depends on further research in time and cost efficiency of DS and CY. Available DM of 389.75 kg/ha support 6.5 AUM per ha and for the grazing period of 4 months, each hectare of this rangeland can carry on 1.62 AU per ha. The current stocking rate of study area is about 0.82 AU per hectare which was suitable based on carrying capacity of study area.

Key words: Clipping and Weighing, Double sampling, Comparative method, Animal-unit-months

Introduction

Rangelands are an important part of the natural environment and the most extensive terrestrial ecosystem. They are important in supplying goods (such as forage, medical plants, honey, etc.) and services (such as soil conservation, recreation, air and water purification, etc.) for human societies (Vermeire *et al.*, 2002; Flombaum and Sala, 2007; Holechek *et al.*, 2011).

High mountain summer rangeland ecosystems are composed essentially of perennial grasses and forbs which make the best pastures of Golestan province in Iran (Hosseini, 2015; Hosseini *et al.*, 2012). These dense grasslands are very efficient in soil conservation and offer standing green fodder for livestock. Many pilot management plans were carried out in these rangelands (Hosseini *et al.,* 2013) but most of the degraded pastures are still suffering from overgrazing and improper range use (Mesdaghi, 2015; Gholami Baghi *et al.,* 2013)

Estimating the total forage production and carrying capacity are the necessities for proper use of these natural ecosystems. But due to the lack of periodic and proper samplings of rangelands, there is no suitable information for estimating biomass, range condition, and management options (Benkobi *et al.*, 2000).

Most estimates of plant production or standing crop include that above ground biomass. This material is commonly available to livestock. But the below ground biomass is also very important for plant functions (Holechek *et al.,* 2011). For estimating the forage production in the rangeland, we need a standard and reliable method to save time, costs, and resources and estimate the production with reasonable accuracy. Direct clipping is considered as the most reliable method of determining the standing crop. But this method is time- consuming and destructive to be practical for monitoring the extensive range areas (Van Dyne *et al.,* 1963; Blankenship and Brown, 1966). Using clipping and weighing method (CW) (Wilm *et al*., 1944; Milner and Hughes, 1968) with an adequate number of samples to evaluate herbage standing crop is expensive and destructive, so a protocol is required that is cost effective, accurate, and rapid.

We have used a simulation model of forage yield (SMFY) to estimate two methods of double sampling (DS) (Cook and Stubbendieck, 1986; Ahmad and Bonham, 1982; Reich *et al*., 1993; Pechanec and pickford, 1937; Arzani and king, 1988) comparative yield (CY) (Haydock and Shaw, 1975), and compared them to CW to recommend a feasible method of estimating herbage production. Although these methods were almost old and recommended in 1980's, but still efficient enough to use for estimating rangeland production (e.g., Bonham, 1989; Mesdaghi, 1993). But due to the lack of high-speed computer simulation model (to replicate thousands random sample), applicability of old findings were restricted.

Double sampling (DS) method is time and cost effective, but requires training of personnel (Cook and Stubbendieck, 1986). The main advantage of the comparative yield (CY) method is that its efficiency can be scaled by the established references (Haydock and Shaw, 1975). More detailed procedures are given in Friedel *et al*. (1988) and Despain and Smith (1987).

Arzani and King (1988) had studied a double sampling method for the estimation of forage production and their results showed that there were no significant differences between actual production and estimated production in the investigated model. Gholinejad *et al.* (2012) studied four methods of Adelaide technique, double sampling, estimating method, clipping, and weighting method (control) for the estimation of forage production in the rangelands of Kurdistan province, Iran. Their results showed that Adelaide method had no significant difference with control,

so it was selected as the best method for estimating the plant production of the study area. A significant difference was obtained between double sampling and clipping and weighting (control) methods which was due to various plant combinations of the study area. Therefore, the double sampling (DS) had lower efficiency than clipping and weighting method to estimate various plant species such as grasses, forbs, and shrubs. But the results of some other researchers did not confirm the above findings (e.g., Mesdaghi and Ajami, 1997; Mesdaghi, 2015).

Another study was conducted by Sadeghinia *et al.* (2003) to compare four methods of? shrub production. Measurements were including: Adelaide technique, double sampling with usage of cover percent for 20% and 25% and direct clipping and weighing method. Their accuracy and time consumption were compared. For this purpose, four species including *Artemisia sieberi*, *Eurotia ceratoides*, *Salsola rigida* and *Aellenia subaphylla* were selected. Their result showed that the best method for all shrubs (except *Aellenia subaphylla*) was double sampling with 20% direct sampling. The Adelaide technique can be an accurate method for *Aellenia subaphylla* because this plant is big in height with sparse distribution of twigs and branches. Therefore, using cover information in the double sampling method was recommended as the best method for shrub production measurement.

The main objective of this study was to contribute better knowledge of rangeland productivity and estimation of carrying capacity through a simulation model of forage yield (SMFY). SMFY is a statistical regression model related to actual weight as dependent variable (*Y*) and estimated weights (*X*) as independent variable which actually are applicable to highly fitted lines of strong correlation (usually more than 90%). In some literature (e.g. Cook and Stubbendieck, 1986), the estimated weights are considered as dependent variables (*Y*) and clipped weight as independent variables (*X*) which statistically are quite incorrect assignments. In fact, the estimated *X's* predicts the actual weights, *Y's* (Mesdaghi, 2015; Bonham, 1989).

The aim of this study was to develop a simulation model for estimating herbage standing crop and grazing capacity in Sar Ali-Abad summer rangelands of Golestan Province.

Materials and Methods

Study area

Sar Ali-abad summer rangeland is a representative of mountain ecosystems of Golestan province. The area of this site is about 780 ha with an elevation ranging from 2100 to 3200 m (Fig. 1). The study area is composed of two management units of Kamerbon and Sameh Chall which are under grazing by two herds of sheep and goats equal to 570 AU (Fig. 2).

The average annual precipitation is about 400 mm that mostly falls in winter as snow. The soil of study area is mostly silty loam to clay loam. The vegetation is composed of grasses of *Agropyron intermedium, A. trichophorum, A. cristatum, Festuca ovin, Hordeum bulboum, Stipa barbata,* and *Poa pulbosa.* The low shrub *of Artemisa sieberi* and spiny cushion shrubs of *Onobrychis cornuta* are accompanying these grasses with *Mesdago sative and Onobrchis sativa* (Pabot, 1967; Hosseini, 2015; Mesdaghi and Ajami, 1997).

Sampling procedure

In five steps, sampling and data collection were made in Sar Ali-abad rangelands.

a) In the first step, in representative stand of the study site, the required sample size was calculated by graphic plots of mean production vs. cumulative plots and using the formula of

$N=(t*CV)^2/A^2$, (1)

Where:

t is table value in Student's *t-test*,

CV is the coefficient of variation and

$A=E/\bar{Y}$ allowable error expressed as a percentage of the mean) (Krebs, 1999) with a thirty 1-m^2 primary plots.

b) In second step, the graduate students of Range Department of University of Agricultural Sciences and Natural Resources were trained for accomplishing DS (double sampling) and CY (comparative yield) by constantly checking the accuracy of their estimates.

c) In the third step, using CY (comparative yield), standing crop yield of five reference plots was searched, selected, and digitally photographed. The ranked reference plots of 1 and 5 had the lowest and highest yields, respectively. Reference plot 3 was chosen to be ranked between 1 and 5 in terms of green biomass yield. Reference plots 2 and 4 were similarly selected to represent quadrate yields were ranked between references 1 and 3 and between references 3 and 5, respectively. Plots were flagged tied to them so that they could be spotted easily in the rangeland. Then, six replications of each ranked plots were searched, clipped, and weighed. The collected plants were air dried, and weighed.

d) In the fourth step, using systematic-random sampling (Chambers and Brown, 1983), 180 plots were sampled for CW, CY, and DS:

- For CY comparative yield), all plots were ranked,
- For DS (double sampling), the green biomass was visually estimated, and
- For CW (clipping and weighing), all of 180 plots were clipped and weighed.

All of the estimations were made using functional types of perennial and annual grasses, perennial and annual forb, grass-likes, and shrubs and using total standing crop of all species together. The clipped biomasses from a subset of 180 plots (37 plots, by 1 in 5) were used for DS. In all plots, the current year's growth was estimated, clipped at ground level, and weighed.

e) Finally, in the fifth step, the ranked and estimated plots were corrected based on regressions of subset of 30 ranked and 37 estimated plots for CY and DS, respectively.

All of our data collections were accomplished during full flower stages of dominant species.

At last, the grazing capacity of study area was determined in animal unit per hectare using the formula of

$$GC = \sum(DM \times AUF)/(AUM) \quad (2)$$

Where:

DM is the Kg dry matter produced per hectare.

AUF is allowable use factor usually determined based on range condition classification (our AUF was 50% as half used and half unused).

AUM is dry matter forage required for one AU (approximate equals a ewe or/goat with kid of 35 kg) in a month per hectare.

GC is grazing capacity expressed in AUM per hectare.

Statistical analysis

To relate the estimated weight to clipped weight, regression models are used (Mesdaghi, 2011):

$$Y_{ri} = \beta_\circ + \beta_1 X_{ri} + \varepsilon \quad (3)$$

$$Y_{ei} = \beta_\circ + \beta_1 X_{ei} + \varepsilon \quad (4)$$

Where:

β_o and β_1 were regression coefficients

Y_{ri} and/or *Yej* was the weight of clipped plots for CY and/or DS

Xri and/or *Xej* was the rank and/or estimated for CY and/or DS.

ε was random error

i=1, 2,....,30 the number of plots for CY

j=1, 2, ..., 37 the number of plots for DS

The 80 ranked and estimated plots were to be corrected by equations (3) and (4), respectively.

The green and dry corrected plots for CY, DS, and for CW were compared using ANOVA at α level of 0.05. All of sampling procedures like locating study site, establishing sample points, and statistical analyses were programmed in R software.

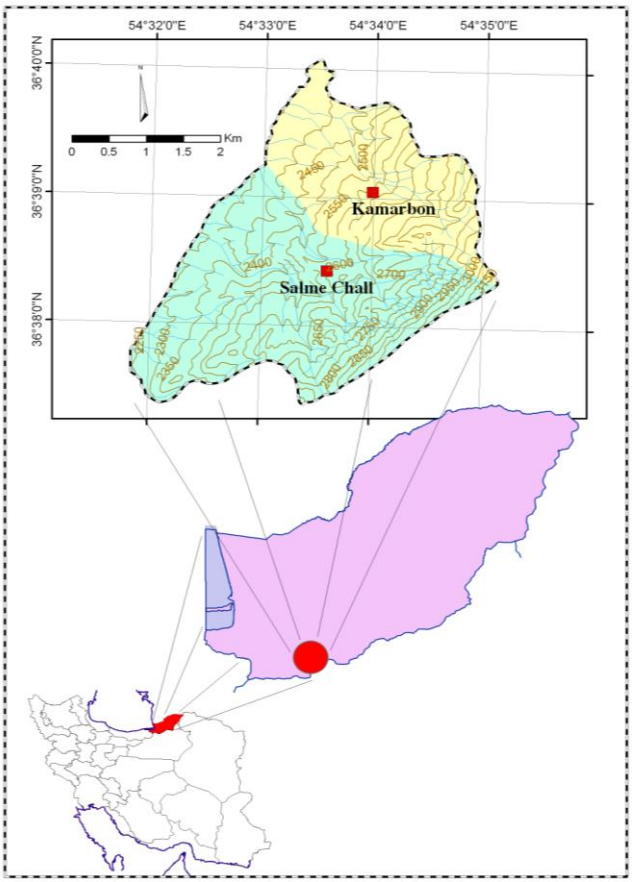

Fig. 1. Sar Ali-abad study location in Golestan Province, Iran

Fig. 2. Sheep and goat grazing in Kamarbon management unit showing uniform utilization

Result and Discussion

Using a primary random sampling size of 30 with 1000 replications, the sample sizes ranges between 170-190 plots, confirming the adequacy our sample size of 180 plots.

The results of ANOVA showed that there were no significant differences among three methods of CW, CY, and DS on the corrected estimations for green and dry forages (Table 1). Linear regression models of CY and DS with the clipped weight of yields are shown in Fig. 3. The high correlations confirm the strong fitness of linear regressions. The mean and standard errors of DM in each method are summarized in Table 2.

Our findings approved that both methods of DS and CY are identical and selecting one of the methods depends on the spatial distribution of vegetation (e.g., dense and disperse). Although some authors preferred the DS (e.g. Gholami Baghi *et al.*, 2013) or CY (e.g. Mesdaghi and Ajami, 1997) to estimate rangeland production, selection of the best method depends on the adequacy of sample sizes and validity of assumptions (normal and independent primary samples). Further research is also needed to evaluate the time and cost consumptions of these methods.

The CY method is more suitable for almost dense uniform grasslands (Mesdaghi and Ajami, 1997; Haydock and Shaw, 1975). But in shrub-lands dominated by specific shrub species, selection of individual shrubs as reference rank plants is preferred to the ranked plots.

After providing production data from our new simulated model, the grazing capacity of study area is precisely determined based on dry matter (DM) of standing crop.

Grazing capacity is usually expressed in terms of animal-unit-months (AUM). An animal unit (AU) is the equivalent of 35 kg animal live weight, which has been defined as a ewe or/ goat with her kid (Mesdaghi, 2015). The animal unit requirement is approximately 60 kg per AUM, and available forage is about 389 kg/ha. The grazing capacity is estimated 6.50 AUM per ha and for grazing period of 4 months, each hectare of this rangeland can carry on 1.62 AU/ha. Currently, the study area was under grazing by 580 sheep and 50 goats equal to 572 AU (=580x0.9+50x1.0). Based on available 700 ha (adjusted for non-usable of cliffy areas), the current stocking rate is 0.82 AU/ha; this range site is not overgrazed. The high mobility and leadership of goats convinced us to consider it as one AU (Mesdaghi, 2015, cited from Traditional pastoralism by Nyerges, 1980).

As the results showed, the study area was properly grazed and there was not any sign of overgrazing even in vicinity of water points and sheep stations (Hosieni *et al.*, 2012; Hosieni *et al.*, 2013). Uniform grazing and short period of grazing season were the main reasons of proper utilization of these summer management units.

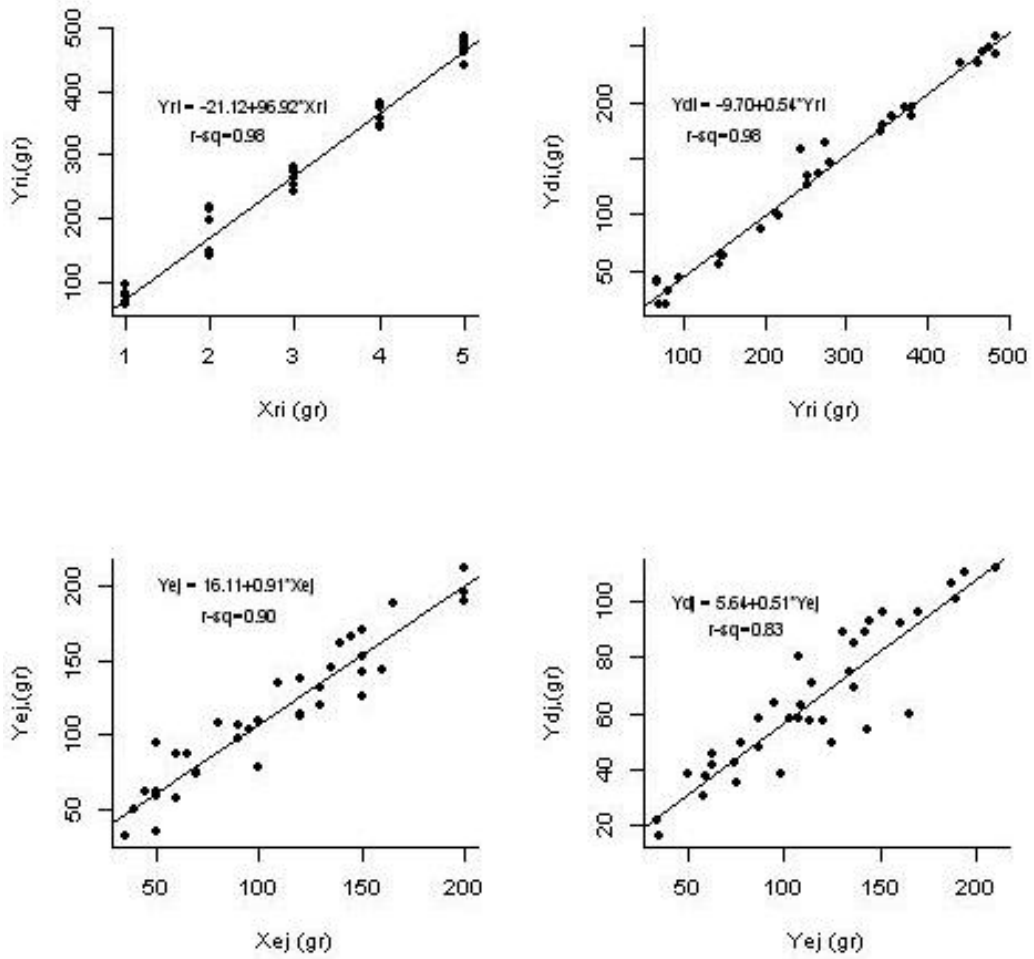

Fig. 3. Regression models of ranked vs clipped green plots and green vs dry plots for CY (above graphs) and regression models of estimated vs clipped green plots and green vs dry plots for DS (blow graphs). Y_{ri} and/or *Yej* was the weight of clipped plots for CY and/or DS ،*Xri* and/or *Xej* was the rank and/or estimated for CY and/or DS. The number of plots for CY was *i*=1, 2,....,30. For DS was *j*=1, 2, ..., 37.

Table 1. The ANOVA of three methods of CW, CY, and DS on corrected estimations of green and dry weights

		Mean Squares		*F*-value		*p*-value	
Source	DF	Green wt.	Dry wt.	Green wt.	Dry wt.	Green wt.	Dry wt.
Methods	2	16128	720	2.4143	0.3946	0.0904	0.6741
Error	537	6680	1824.5				
Total	539	22808	2544.5				

α, level of significance equals 0.05.

Table 2. Comparison means of dry matter estimates of CY, DS, and CW

Estimating Method	Dry matter yield(Kg/ha)	SEM
Clipped and weighed method (CW)	779.5[a]	±3.19
Comparative Yield method (CY)	766.0[a]	±3.57
Double sampling method (DS)	805.2[a]	±2.74

Same upper cases were not significant at 0.05.

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برآورد تولید علوفه سرپا و ظرفیت چرا با استفاده مدل شبیه‌سازی محصول علوفه در مراتع ییلاقی سرعلی آباد استان گلستان، ایران

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چکیده. جهت دستیابی به روشی صحیح و سریع برای برآورد تولید علفزارهای ییلاقی شمال شرق کوه‌های البرز ایران، از روش‌های نمونه‌گیری دوبل (DS)، برآورد محصول مقایسه‌ای(CY) و از روش قطع و توزین (CW) استفاده شد. روش به کار گرفته شده، مدل شبیه‌سازی محصول علوفه (SMFY) خوانده شد تا تأکیدی بر روی جنبه‌های آماری مدل شود. در توده‌های معرف تیپ علفزار، پنج پلات مرجع انتخاب شد تا معرف دامنهٔ محصول علوفه تولیدی منطقه باشد. با استفاده از طرح سیستماتیک- تصادفی، ۱۸۰ پلات یک مترمربع، در مقایسه با پلات‌های مرجع، رتبه‌بندی شد و با روش نمونه‌گیری مضاعف به‌طور نظری تولید آن برآورد گردید. در پایان کار کلیه ۱۸۰ پلات‌ها قطع و توزین شدند. بعد از قطع و توزین ۶ تکرار از هر پلات مرجع و برآورد نظری تولید ۳۷ پلات یک مترمربعی، بین پلات‌های برآورد شده و رتبه‌بندی شده و قطع و توزین شده خطوط رگرسیون بر روی پلات‌های برآورد/ رتبه‌بندی شده در مقابل پلات‌های قطع شده خطوط رگرسیون تطبیق داده شد. این مطالعه طی سال‌های ۹۲-۱۳۹۰ انجام شده است. برای دو روش نمونه‌گیری مضاعف و مقایسه‌ای همبستگی بالایی (۰/۹۹—۰/۹۰) ثبت گردید که داده‌های برآورد و رتبه‌بندی شده براساس معادلات رگرسیون تصحیح شدند. بین داده‌های تصحیح و قطع شده برای روش‌های نمونه‌گیری دوبل، برآورد محصول مقایسه‌ای روابط خطی قوی وجود داشت که مؤید مناسب بودن هر دو روش مقایسه‌ای و دوبل در مقایسه با روش قطع و توزین بود. لذا کلیه ۱۸۰ پلات برآوردی براساس معادلات رگرسیون تصحیح و سه روش با استفاده از تحلیل واریانس مقایسه شدند که معنی‌دار نبودن آزمونF مؤید کارایی دو روش DS و CY بود. ترجیح یکی از دو روش بستگی به تحقیقات بیشتر بر روی کارایی آنها از نظر زمان و هزینه مصرف شده دارد. مقدار ماده خشک تولیدی ۳۸۹/۷۵ کیلوگرم در هکتار از ۶/۵ واحد دامی AUM در هر هکتار برای دوره چرای چهار ماهه حمایت می‌کرد که معادل ۱/۶۲ واحد دامی در هکتار بود. تعداد دام فعلی در هر هکتار حدود ۰/۸۲ واحد دامی در هکتار بود که مؤید بهره برداری متناسب با ظرفیت مرتع بود.

کلمات کلیدی: قطع و توزین، نمونه‌گیری دوبل، روش مقایسه‌ای، واحد دامی در ماه