The Animal-Unit and Animal-Unit-Equivalent Concepts in Range Science

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Abstract

The terms animal-unit and animal-unit-equivalent have evolved as a means of expressing different kinds and classes of livestock in a common form. This paper discusses the evolution of the concepts, analyzes their conceptual boundaries, and discusses their use in the analysis of range livestock systems. Recent efforts to modify these concepts to develop livestock species substitution ratios for specific ranges are discussed. For greater usefulness in describing range livestock systems, animal-unit-equivalents should be calculated based only on animal-related factors. Also, the animal-unit-equivalent concept should not be redefined in the calculation of pasture-specific substitution ratios.

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While the animal-unit (AU) and animal-unit-equivalent (AUE) are familiar terms to most range scientists, there is considerable variation in the definition and use of these concepts. Recent papers by several investigators in different countries show divergent interpretations and applications of them, producing inevitable confusion. This paper (1) discusses the origins of the animal-unit and animal-unit-equivalent, (2) defines their conceptual boundaries, (3) examines their usefulness in deriving species substitution ratios under common-use grazing, and (4) describes their applications in range science.

Origins

The cow-day, a forerunner of the animal-unit-day (AUD), has its origin in the range reconnaissance survey method developed in part by Jardine between 1907 and 1911, while working as an inspector of grazing for the U.S. Forest Service. Jardine and Anderson (1919) addressed the question of substitution ratios for cattle and sheep under common use grazing, but used neither the term animal-unit nor cow-unit. Sampson (1923) used the term cow-unit in describing grazing capacities. He stated that 1 cow-unit was the equivalent of 5 sheep or 5 goats, but did not otherwise define the cow-unit. Pickford (1940), in a glossary following a paper on range survey methods, defined an animal-unit as the amount of forage grazed by a mature cow *in 1 year*, and further stated that 5 sheep, 5 goats, or 1 horse were considered equal to 1 cow for range grazing. This definition is essentially the animal-unit-year as defined years later by the Society for Range Management (1974).

Stoddart and Smith (1943) used the term animal-unit in calculating carrying capacities, and although they did not define the term, its use was apparently the same as that of Sampson (1923), described previously as the cow-unit. Twelve years later. Stoddart and Smith (1955) had removed the term animal-unit from discussions of carrying capacity in the second edition of *Range Management*, but as a footnote to a table on page 2 of that book defined an animal-unit as "1,000 lb liveweight, or roughly equivalent to the weight of a cow and a calf." This definition, and another table (page 192) in that book (Stoddart and Smith 1955), suggest that the authors had adopted a liveweight approach to defining an animal-unit. Under this approach a 454 kg (1,000 lb) animal of any species was equivalent to 1 AU, while a 227 kg (500 lb) animal of any species was equivalent to 0.5 AU.

Three years earlier, Sampson (1952) had defined the animal-unit as "the forage requirement of a mature cow for 1 year," further stating that 5 sheep or 5 goats were generally regarded as equal to 1 cow for range grazing. This definition, like that of Pickford (1940), is essentially an animal-unit-year as later defined by the Society for Range Management (1974).

Thus, as of the mid-1950's, the animal-unit was *explicitly* defined only in terms of animal liveweight (Stoddart and Smith 1943, 1955), but was *implicitly* being *used* to equate forage consumptions among different livestock species under common use grazing, and thereby determine substitution (exchange) ratios. Up to that time, the animal-unit concept had not been rigorously defined, and consequently, while it may have been occasionally applied in practical management, it was not widely used in published work. Widespread use required a more rigorous definition, and a better understanding of its uses and limitations.

Vallentine (1965) attempted to address this problem and defined the animal-unit as a mature, 454 kg dry cow in maintenance or gestation, or its equivalent. From this definition, he derived animal-unit-equivalents for different classes of cattle. In his paper, the animal-unit and animal-unit-equivalent were applied only to cattle; there were no interspecific applications.

Conceptual Boundaries

To understand the animal-unit and animal-unit-equivalent concepts, one must understand differences between 3 different definitions of the animal-unit. Voisin (1959) defined the animal-unit as 500 kg of intraspecific animal liveweight, which is similar to the definition of Stoddart and Smith (1955), although Stoddart and Smith did not limit their definition to intraspecific comparisons. In Voisin's approach, if a herd is composed solely of cattle, the weight of the herd is summed and divided by 500 kg, thus giving the total number of cattle animal-units in the herd. Under this definition, a 250-kg heifer is equivalent to 0.5 AU, while a 500-kg cow or bull is equivalent to 1.0 AU. Voisin (1959) specifically assumed that: (1) an animal of 250 kg should consume half as much forage as an animal of 500 kg; (2) an animal of 750 kg should consume one and one half times as much forage as an animal of 500 kg, and; (3) a lactating cow should consume the same amount of forage as a dry cow. It is significant that this definition of the animal-unit involves only one variable, animal weight, and contains no herbage or environmental variables.

Questions concerning the validity of the above assumptions of Voisin (1959) led to a metabolic size definition of the animal-unit. This approach is discussed in detail by Edwards (1981). Several similar but slightly different definitions have been proposed as the basis of the metabolic size approach. Edwards (1981) stated that the basis for the animal-unit should be considered a 450-kg steer at 30 months of age. Edwards' animal-unit was explicitly defined in terms of an animal of a specific weight and implicitly defined in terms of the metabolic requirements of an animal. Following the work of Kleiber (1975), the animal-unit-equivalent of an animal was calculated by the equation $X = (M/450)^{0.75}$, where X is in animal-units, and M is the animals's weight expressed in kilograms. This approach addresses the first 2 stated assumptions (limitations) of Voisin's weight approach, but the third limitation remains, e.g., a lactating cow and a dry cow of equal weights are calculated to have the same animal-unit-equivalent.

An earlier but more explicit definition was proposed by the Society for Range Management (1974). The Society defined an animal-unit to be a mature 454-kg cow or equivalent with an average for consumption of 12 kg of dry matter (DM) per day. In this case, the animal-unit was defined explicitly in terms of both an animal weight and what is essentially a daily potential intake or animal demand. This approach was also implicitly based on the metabolic size equation because the potential intake of an animal was assumed a function of its metabolic size.

Examination of the 3 definitions of the animal-unit (Voisin 1959, Edwards 1981, Society for Range Management 1974) suggests that it is more useful to define the effect of an animal on a pasture and vice versa in terms of an animal's metabolic size rather than its weight. In turn, it is more useful to describe this mutual effect in terms of an animal's demand on the pasture (i.e., potential intake), than simply in terms of its metabolic size. The potential intake approach allows consideration of the differential demand of different classes of livestock, e.g., the differential demand of a lactating cow versus a dry cow.

Hodgson (1979), in a discussion of grazing terminology, referred to the usefulness of a potential intake approach to describing grazing relationships. Simply, the potential grazing effect of an animal on a pasture is determined not by how much the animal weighs, but on its potential herbage intake, or animal demand. To use a potential intake approach to describe animals on pasture, a unit of potential intake (= animal demand for forage) is needed.

Scarnecchia and Kothmann (1982) simplified the definition of the animal-unit and defined it simply as a unit of animal demand equal to 12 kg DM per day. The 12 kg DM/day figure was adopted to be as consistent as possible with the definition of an animal-unit suggested by the Society for Range Management (1974) and is based only on potential intake, without regard to losses to fouling or trampling. The 12 kg DM/day may be either too high or too low to describe the demand of a mature cow. While the figure was adopted for convenience by the Society for Range Management to approximate the demand of a mature cow, so that a cow could equal 1 AU, the figure is in every other sense arbitrary and designed only to quantify the animal-unit. Under the simplified definition of Scarnecchia and Kothmann (1982), the animal-unit is a unit of demand analogous to the meter as a unit of length.

The definition of Scarnecchia and Kothmann (1982) is the basis for developing time-dynamic animal-unit-equivalents and an entire-time-dynamic grazing terminology. With the animal-unit defined in this way, the demand of any animal can be expressed in animal-units. The animal-unit-equivalent is then the animal demand of an individual animal expressed in animal-units and is a function of animal-related factors which affect the animal's potential intake, including metabolic size, gestation, or stage of lactation; i.e. AUE = f(MS, P, L, etc.). In this way, the differential demand of, for example, a lactating cow and a dry cow can be considered in calculations of stocking density, stocking rate, grazing pressure and other stocking variables described by Scarnecchia and Kothmann (1982), and more accurate calculations of stocking variables are possible.

This definition of the animal-unit-equivalent does not include herbage or environmental characteristics. Thus, an animal-unit-equivalent of an animal is independent of herbage or environmental factors; it is a function of only animal factors such as metabolic size, gestation or lactation.

There is justification for limiting the boundaries of the animal-unit-equivalent concept in this way. Figure 1 is a simplified conceptual model of some factors affecting daily herbage intake. In the model, intake is affected by factors which are conceptually animal-related (AUE), herbage-related (cell wall content), environmental (ambient temperature), animal-herbage related (suitability index), and animal-herbage-environmental (energy expenditures). In analyzing the system, we attempt to isolate the effects of *individual* variables on other *individual* variables, e.g., the effect of cell wall content on intake, or the impact of adding an additional animal-unit of demand on daily herbage intake. If the animal-unit-equivalent (=animal demand) is defined as a composite of animal,

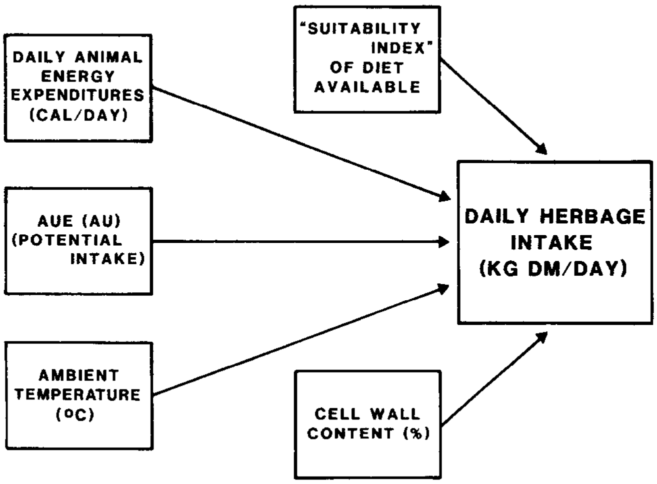

Fig. 1. *A simplified conceptual model of some variables affecting actual herbage intake of a grazing animal on pasture. If stocking rates or other stocking variables are to be compared between pastures or between studies, the animal-unit-equivalents used in their calculation must be independent of the environmental, herbage, or animal-herbage factors shown, even though these factors may affect actual herbage intake.*

herbage and environmental factors, it is confounded with all of these other factors. Although suitability index, ambient temperature, and the other variables in Figure 1 will affect actual herbage intake, they should not affect the potential intake underlying the animal-unit-equivalent concept. Instead, a particular animal must have an animal-unit-equivalent independent of the kind of herbage it is eating or the temperature of its environment; an animal must have the same animal-unit-equivalent whether in a pasture or in a feedlot. Only by making the animal-unit-equivalent purely an animal-related variable can it be conceptually separated for systems analysis as a distinct variable, rather than a pasture-specific composite of limited use.

Animal-unit-equivalents are used in calculating stocking rates and all other stocking variables. It is impossible to compare stocking rates or other stocking variables between any 2 pastures if the animal-unit-equivalents in those stocking rates are specific to each pasture. For example, a single herd of animals on 2 different pastures of equal size can only represent 1 stocking density, not 2 different densities based on differences in species composition between pastures. Only by basing animal-unit-equivalents on only animal-related factors can comparison of stocking variables between pastures, years, or studies have meaning.

Substitution Ratios

The animal-unit was developed partially to provide a common basis for describing grazing by different animal species on ranges. On a specific range, the number of animal-units of one species (e.g., sheep) which may be substituted for another species (e.g., cattle) has been a frequently asked question. It has long been accepted (Jardine and Anderson 1919) that because some forage species are not preferred by some kinds of livestock, some ranges are better suited to one kind of livestock than to another. Recent investigators (Flinders and Conde 1980, Botha et al. 1983) have attempted to calculate pasture-specific substitution ratios by adjusting animal-unit-equivalents for different animal species based on the average dietary overlaps of these animal species on a specific type of range. These investigators proposed the equation $X = 450^{0.75}/((M^{0.75})(\%$ dietary overlap$))$ to calculate animal-unit-equivalents, thus redefining the animal-unit-equivalent concept.

While the relative suitability of a range type to a particular kind of livestock is important in management, incorporation of this dietary overlap factor into the animal-unit-equivalent concept is disadvantageous for 2 reasons. First, the dietary overlap of 2 animal species is subject to many variables, including season of use, stocking density, and stocking rate. Use of a single percentage figure to cover all combinations of even these 3 factors is inadvisable because dietary overlap can vary greatly with changes in these 3 and other variables. The dietary overlap of 2 species on a particular pasture is highly dynamic, and therefore, not generally useful in calculating substitution ratios.

Second, the dietary overlap percentage should not be used to adjust animal-unit-equivalents as has been proposed because it redefines the animal-unit-equivalent by incorporating an herbage-related factor. From a systems perspective, integration of a pasture-specific dietary overlap figure into the animal-unit-equivalent makes the animal-unit-equivalent less useful as a variable for analysis. Since stocking density, stocking rate and other stocking variables are calculated using animal-unit-equivalents, their meanings are equally unclear under this type of adjustment. The problem of how many sheep to substitute for a cow on a particular pasture to satisfy management goals is a separate and more complex management problem beyond the animal-unit and animal-unit-equivalent concepts. Calculation of substitution ratios on specific ranges involves explicit statement of goals, and for most goals is a modeling problem of many variables, including animal-unit-equivalents.

Applications of the Concepts

No 2 animals in a pasture will behave in exactly the same way. Animal-unit-equivalents are more meaningful and useful in collectively describing animals with similar diets. Thus, animal-unit-equivalents are most meaningful *intra*specifically, and even more meaningful within intraspecific classes of livestock; they are less meaningful *inter*specifically. For example, the effect on a pasture of stocking 100 AU of 300-kg steers should be similar to the effect of stocking 100 AU of 400-kg steers. Comparatively, the effect of stocking 100 AU of mature cows should be less similar to the effect of stocking 100 AU of 300-kg heifers. By further comparison, the grazing of 100 AU of cattle will be even less similar to stocking 100 AU of sheep, goats, or different wildlife species, because the differences in diet selection between species are usually greater. The animal-unit-equivalent concept is best applied as an intraspecific tool, rather than as an interspecific one.

Consequently, stocking densities, stocking rates, and other stocking variables containing animal-unit-equivalents are more meaningful if calculated and expressed intraspecifically. Used in this way, the animal-unit approach offers a more accurate way of calculating stocking rates, etc., of a group of animals of different sizes, growth rates, and physiological states. Because all of the effects of a group of animals on pasture cannot be contained in one number (the AUE), it is still important to keep grazing records of animal numbers and characteristics. If defined and applied rigorously, the animal-unit and animal-unit-equivalent concepts and the stocking variables derived from them are a useful part of describing range livestock systems.

Conclusions

Based on the foregoing discussions I have concluded the following: first, the animal-unit should be considered a unit of animal demand (potential intake). The animal-unit-equivalent concept has evolved from one based either implicitly or explicitly on weight, metabolic size, or other one-variable models, to one based on animal demand. An animal's effect on a pasture, and vice versa, is a function of metabolic size, lactation, gestation, and other variables contributing to animal demand, not simply animal weight, metabolic size, or any other single variable. Determination of animal-unit-equivalents using such a multi-variable animal demand model allows more precise calculation of stocking variables like stocking rate.

Second, animal-unit-equivalents should be calculated based only on animal-related factors, including animal weight, lactation, gestation, and other animal factors which affect animal demand. For this potential intake approach to be most useful, it should be applied intraspecifically. General, standardized animal-unit-equivalent models should be developed for different kinds and classes of livestock. The animal-unit approach does not eliminate the need or usefulness of keeping grazing records on animal numbers or characteristics.

Third, adjustment of animal-unit-equivalents based on dietary overlap estimates for specific pasture types should not be attempted because this approach violates the boundaries of the animal-unit and animal-unit-equivalent concepts and makes the animal-unit-equivalent, and stocking variables derived from it, less useful for analysis and comparison of range livestock systems. Calculation of substitution ratios among different kinds of livestock on a particular range is a separate problem, possibly requiring use of the animal-unit and animal-unit equivalent, but not justifying their redefinition.

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