A Simple Method of Measuring Travel Distance of Livestock in Pasturing

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Measurement of travel distance of livestock on pasture is regarded requisite in studying the ecology of livestock such as its energy balance, and also the vegetation succession as affected by treading.

Methods of measuring the movement of fluid or suspension in the fluid, for example smoke in the air, are generally classified into what is called the Lagrange type and the Fuler type. The former, which pays attention to the fluid or suspension itself, traces the loci of its movement or the pattern of its diffusion, and analyzes results thus obtained, while the latter method sets up a fixed location for observation, and traces and analyzes changes which occur at the location. According to this classification, methods which have been employed so far in measuring the travel distance of livestock belong to the former type.

To determine the travel distance by the conventional method so far used, the loci of the livestock travel are required. For that purpose, (1) tracing by photographing, (2) tracing by the use of telemeters, etc., and (3) tracing by field workers have been deviced and used. In the case of (1) and (2), an enormous time is needed to reproduce the loci, and in (2) expensive instruments are required. In the case of (3), there is a limitation that the behavior of livestock is interferred by human being, i.e., a problem beyond the question of data collection.

By the method of the Euler type, analysis can be made by knowing the passage frequency of livestock across the fixed line, so that the movement of investigators and instruments is not needed. Data can be obtained with less expenditure and remarkably less labor, if an appropriate recording method is used. However, the degree of accuracy may possibly be more or less low.

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Theoretical basis of the line method

If the movement of livestock in a paddock with a limited area is presumed to be similar to that of a complete elastic body, the frequency of livestock passage (N_w) across a fixed line (with length of w), which is set up in the rectangular paddock (with width of w, and length of l) in parallel to the fence, is expressed as:

$$N_w = d \sin \alpha / l \quad \text{......(1)}$$

where d=travel distance per unit time

α=travel direction against one side of paddock.

If α is presumed to take all values eqaully, the equation (2) can easily be derived from the equation (1):

$$\sum d = \frac{N_w l}{\frac{\int_0^{\frac{\pi}{2}} \sin \alpha d\alpha}{\pi/2}} \quad \text{......(2)}$$

where $\sum d$=total distance of travelling

Because the denominator of right term is $\pi/2$, and the area of the paddock is lw (=s), the equation (2) is expressed by

$$\sum d = \frac{\pi}{2} S \frac{N_w}{w} \quad \text{......(3)}$$

The equation (3) is obtained on an assumption that the fixed line runs parallel to one side of the paddock and its length is equal to the width of the paddock, but the equation stands regardless of the direction and length of the line, as far as the assumption that livestock travel equally in all directions is satisfied.

Now, by using the equation (3) the travel distance was calculated for the loci shown by Ohno and Tanaka[3], and as a result the following facts were known:

1) When the ratio (δ) of travel distance/averaged length of diagonals (paddocks are not always strict rectangles) is less than 5, large variations occurs in estimations because smaller δ means less traverse frequency.

2) With the fixed line running in parallel with the short side of a rectangle, the estimated distance tends to be longer than the actual distance, suggesting the behavior of livestock to move along the boundary, i.e., the tendency to travel more frequently in the direction of length.

3) When two diagonals are used as fixed lines, errors of about 25% occur in estimation at $\delta=5$.

4) Even with a single fixed line, the error is about 15% in case of $\delta>25$.

For a round-shaped paddock, 2.0 is used instead of $\pi/2 \fallingdotseq 1.6$, and for extremely long paddock, which prevents livestock from free change of direction, 1.0 is used instead of $\pi/2$.

Set up of the line in paddock with a large length/width ratio

In the paddock with a long rectangular shape or with remarkable slope, livestock move with high frequency along the long side of rectangle or contour lines. In such cases, overestimations of the distance occur when the fixed line is set up transversely to the rectangle or at right angles to the contour lines. In this case, two fixed lines, in the x direction (width-wise) and the y direction (length-wise) are set up, and frequencies of livestock passage at each line, Nx and Ny, are substituted into equation (2). Then,

$$\sum d = \frac{\pi}{2}\sqrt{S}\sqrt{N_x N_y} \quad \text{..................(4)}$$

is obtained. Namely, the estimate can be obtained from the geometrical average.

An application of this method to an example ($\delta=10-15$) reported by Kubo and Morozumi[2], showed an error within a range of 15%.

Now, the ratio (C) of the travel component in the x direction to that in the y direction is defined as

$$C = \frac{\sum f_i \cos \alpha_i}{\sum f_i \sin \alpha_i} = \frac{p}{q} \quad \text{..................(5)}$$

where f_i = frequency

α_i ($i=5, 10, \ldots, 90°$) = travel direction against the fixed line

Therefore, p and q indicate the total travel distance projected to the x direction and the y direction, respectively.

If there is no inhomogeneity in travelling, relationships of $Nx=q/l$ and $N_y=p/w$ can stand. Then taking the equation (5) into consideration, the following equation can be obtained:

$$\sum d = \frac{\pi}{2}\frac{s}{w}N_x\sqrt{C} = \frac{\pi}{2}\frac{s}{l}N_y\frac{1}{\sqrt{C}} \cdots\text{(6)}$$

There is a relation that $C=p/q=Ny\ w/Nx \cdot l$, l and w being constants of a given paddock, so that C can be obtained by measured values of N_x and N_y. If the types or characteristic of the loci of livestock travel do not vary with the time of day, the estimation of travel distance can be made using a single fixed line, by determining C in advance.

Examples of estimation by the line method

1) Paddock and locus of livestock shown in Fig. 1.

The paddock is of undulating topography and has a ratio of length/width close to 1. The locus is uniformly distributed in the whole area, except a portion adjacent to D where somewhat heavier distribution is recognized.

Based on the assumption that the fixed line

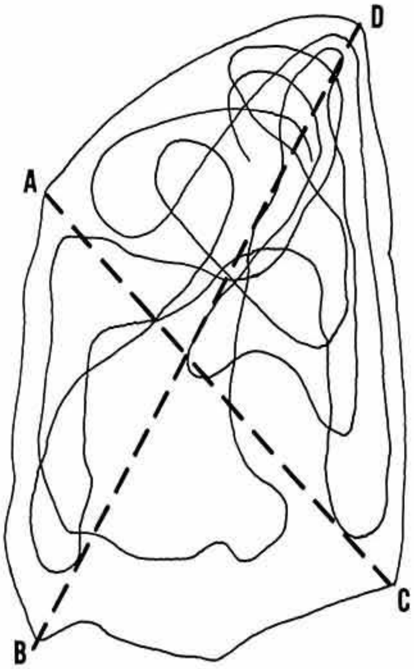

Fig. 1. An example of locus of cattle in Aichi Prefectural Mountains Station for Breeding Stock Rearing[3)]

was set up as AC or BD, each point where the locus intersects the fixed lines is counted as 1 in estimating the frequency of livestock passage across the fixed line. Then

Fixed line	No. of passage	Length of fixed line	Paddock area
AC	13	332 m	4. 9 ha
BD	7	251 m	

According to the equation (3), $\sum d$ is calculated as follows:

$$\sum d\ (\text{AC}) = \frac{\pi}{2} \times 4.9 \times 100\text{m} \times 100\text{m} \div 332\,\text{m} \times 13 = 3,010\text{m}$$

$$\sum d\ (\text{BD}) = \frac{\pi}{2} \times 4.9 \times 100\text{m} \times 100\text{m} \div 251\,\text{m} \times 7 = 2,150\text{m}$$

As the actual distance was 2,860 m, the AC estimate was 5% higher and the BD estimate 25% lower than that. With this paddock, which has averaged length of diagonals of 292 m, and $\delta=10$, somewhat a large error was anticipated. The errors will be reduced when δ increases.

2) Paddock and locus of livestock shown in Fig. 2.

The paddock is sloping and has a length/width ratio of 3.6.

Fixed line	No. of passage	Length of fixed line	Paddock area
x-direction, PP′	N_x : 17	w : 293m	2. 4 ha
y-direction, QQ′	N_y : 13	l : 82m	

Using the equation (4), $\sum d$=3,620 m was obtained.

$$\sum d = \frac{\pi}{2} \times \sqrt{2.4 \times 100\text{m} \times 100\text{m}} \times \sqrt{17 \times 13} = 3,620\,\text{m}$$

As the actual distance was 3,450 m, the error was about 5%. As $C = Ny \cdot w / Nx \cdot l = 13 \times 293 / 17 \times 82 = 2.7324$, $\sqrt{C} = 1.653$.

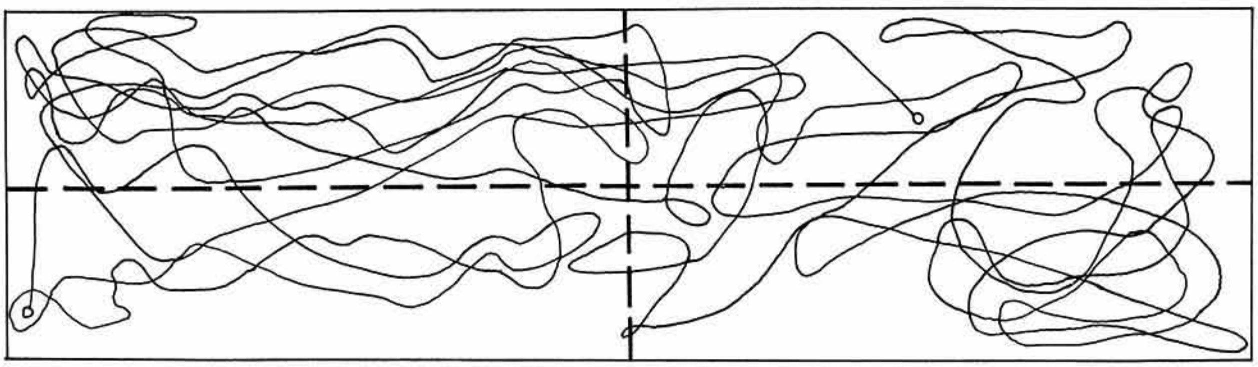

Fig. 2. An example of locus of cattle in Alpine Region Branch, National Grassland Research Institute[2)].

In practice, the measurement of livestock passage can be made without human labor by using camera with automatic exposure at a 2–10 second interval.

References

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