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Optimal Rangeland Management for Sustainable Livestock Farming

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Abstract: Rangeland is often described as the farmer's *cheapest fodder source*. Although there is inherently nothing wrong with this statement, it is only true if the rangeland is in a good condition. To obtain a rangeland that is in good condition it is necessary to practice optimal rangeland management. With *optimal rangeland management* an endeavor is made to maintain the long-term productivity of the rangeland, while the yield of animal products such as wool, meat and/or milk are maximized. To achieve optimal rangeland management factors like stocking rate and management systems are important, but the most important factor is healthy, perennial grass plants with excellent root systems. For a farmer to achieve optimal rangeland management it is thus necessary to look after the root systems of the grass plants and this can be achieved through proper rest systems in the rangeland.

Key words: management systems, stocking rate, rangeland rest, plant growth

1. Introduction

Rangelands collectively represent about 7% of the world's land surface [1, 2] and are home to 2.1 billion people — approximately 35% of the world's population [1]. In spite of the fact that the rangelands of the world is often described as degraded [3, 4] one often hear the following statements: "The most valuable asset in livestock farming is rangeland" or "Natural grazing (rangeland) is the cheapest way meat is produced" and the most common one "Rangeland is the farmer's cheapest fodder source" [5-7]. When the last statement is typed into Google, there are over 30 000 written results where this statement has already been used. Although there is inherently nothing wrong with any of these statements, all can be considered as incomplete. Rangeland is only a cheap and good fodder source *if* it is in a *good condition* — rangeland in a good condition will lead to climate smart livestock productions where enteric emissions are relatively low [7]. Rangeland management is one of the most difficult aspects of farming. Poor rangeland management often leads to poor, unproductive rangeland which negatively affects farming efficiency and in the end leads to higher enteric emissions from ruminant livestock [7]. To achieve good rangeland management, it is essential that not only the stocking rate should be closely monitored, but sound management principles, especially aimed at the grass plant/roots, should also apply. To achieve the latter, it is important that the growth and development of the grass plant, but especially the health of the grass roots, are taken into account [5, 6].

2. Optimal Rangeland Management

The main purpose of *optimal rangeland management* is to maintain the long-term productivity of the rangeland, while the yield of animal products such as wool, meat and/or milk are maximized. From a practical point of view, the functions of optimal rangeland management is to maintain a consistent supply of feed for the animals, but at the same time

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ensuring that the rangeland is not being overgrazed [5-8].

Successful climate smart animal production should be the core of livestock farms because it determines the amount and the quality of the animals produced, while it will also affect the long-term sustainability of the grazing strategy. The two main variables that are under direct control of the landowner and that will determine the success or failure of its rangeland management strategy are the stocking rate and the grazing system. The stocking rate refers to the number of animals maintained per unit area on the farm and the grazing system refers to the frequency and length of occupancy of the animal in the paddocks and/or grazing areas on the farm [8].

2.1 Stocking Rate [8-12]

Stocking rate is the single most important determining factor in determining the ecological sustainability of farming. This is because stocking rate is the primary determinant of the amount of vegetation biomass that are removed each year by the livestock on the farm/area — in other words, it determines the impact of livestock on the vegetation. The exact pattern in time and space in which the biomass is removed depends on the grazing system. The recommended stocking rate is calculated as the rate where peak animal performance will take place — where performance is measured in terms of average daily weight gain (ADG). The recommended stocking rate is the rate where maximum animal production is likely to occur — this is NOT the maximum number of animals that can be maintained. There are several factors that can reduce the actual sustainable stocking rate of the ideal maximum and that should be taken into account. These include the following:

- Rangeland degradation — the grazing capacity of degraded rangeland is generally lower than that of rangeland in good condition. Degraded rangeland gives rise to a lower total annual production and/or changes in the composition of the rangeland from good to bad. The stocking rate in degraded rangeland is lower than rangeland in good condition.
- Drought — dry years, especially when they occur in consecutive years, can reduce the perennial vegetation cover and hence the number of animals that the rangeland can sustain. It is recommended that livestock numbers should be reduced drastically during prolonged droughts – it has already been scientifically proven that high stocking rates during drought conditions had a significant impact on rangeland recovery after the drought.
- Animal type/breed — certain types and species of animals have a greater impact on the veld than others (sheep vs. cattle or large frame animals vs. medium and small frame animals). In the determination of the stocking rate these aspects should be taken into account.
- Grazing system — some grazing systems cannot support the same number of animals in a sustainable way as other systems. With continuous grazing or systems similar to continuous grazing, the stocking rate should be lower than in other grazing systems since this type of system leads to rangeland degradation.

2.2 The Importance of Grazing Systems and Rangeland Rest

A grazing system is a formalized program of rangeland management through which rangeland management practices are applied. It thus refers to the manner or pattern the paddocks are used and rested. At the most basic level, grazing systems can be divided into two categories, namely continuous grazing and rotational grazing [13]. It is a known fact that grazing practices can play a significant role in soaking up carbon. Simple changes in grazing practices could soak up millions of tons of carbon in a year, thus help fighting climate change, improving farm productivity and earning farmers carbon credits. Up to 1.3 to 2

billion tons of carbon can be stored by 2030 if better grazing practices are implemented worldwide [14, 15]. The following are examples of different grazing practices:

2.2.1 Continuous Grazing

Continuous grazing is a type of management whereby animals are placed in a camp when the forage becomes ready for grazing at the start of the growing season and they or their replacements are left in that camp for the entire grazeable period of each year [16]. Continuous grazing is the simplest system that can be applied (and is mostly applied in communal areas of South Africa), since the only thing that can be customized, is the stocking rate [8]. In this system the animals have access to the same grazing area for the whole year. This system works well if the stocking rate is low — if economically viable stocking rates are used, both the animals and the rangeland won't suffer. If animals are allowed to move freely through the rangeland only the palatable grasses or parts of grasses will be removed. Repeated removal of these materials affects plant vigor as well as the reproduction thereof. Continuous grazing is not recommended as an economically sustainable system and it is also not recognized as part of Climate Smart Agriculture (CSA) — firstly, because it is highly unlikely that low stocking rates will be maintained and, secondly, even under low stocking rates the animals will prefer certain areas more than others which can and will lead to overgrazing [7, 8].

2.2.2 Rotational Grazing

Rotational grazing is a type of management which requires the grazing allotted to a group or groups of animals for the entire grazeable period, to be subdivided into at least one (usually more) paddock more than the number of animal groups. It involves successive grazing of the paddocks by the animals in a rotation so that at any time the animals are concentrated on as small a part of the grazing available to them during the entire grazeable period, as fencing will permit [16]. Rotational grazing systems can again be divided into two broad categories, namely those who use short grazing periods (less than a month) and those using longer grazing periods (two months or longer per paddock or area). The system that use short grazing periods is known as Non Selective Grazing (NSG) and Holistic Resource Management (HRM). The systems that use longer grazing periods are known as Controlled Selective Grazing (CSG) [8].

(1) Non Selective Grazing

Non selective grazing (NSG) is the occupation of a paddock by grazing animals until all the grass species have been heavily grazed [17]. Non selective grazing is also known as High Utilization Grazing or High Density/Pressure grazing or even as Ultra High Density/Pressure Grazing. In this system, rangeland is grazed by a high stocking rate for a short period. The idea behind this system is that the high stocking rate will reduce selective grazing and the animals are actually forced to also graze the unpalatable species. It thus reduces the competitive advantage that the unpalatable species have over the palatable species in a selective defoliation system. In order to achieve this, high stocking rates, small paddocks, or more generally, electric fences are used. After the grazing period the rangeland is rested for a long period – usually a year or even longer [7, 8].

(2) Holistic Resource Management

Holistic Resource Management (HRM) is a whole farm planning system that helps farmers better manage agricultural resources in order to reap sustainable environmental, economic and social benefits [18]. HRM falls in the same class as NSG since both use short grazing periods, but the aims of the two systems are very different. The basic argument of HRM is twofold — firstly by grazing the palatable species on a regular basis, HRM tries to increase the vigor and annual production of these species; and secondly, by using large quantities of animals HRM attempts to simulate ecosystem processes such as decomposition and nutrient cycling. The grazing pressure in HRM may vary from moderate to high depending on the

season and growth stage of the plants. The rest periods in this system are usually short, between 2-3 months, depending on the rainfall. Since plants are more often grazed in this system compared with NSG, the stocking rate should be adjusted on a regular basis as well as for each section that is grazed. This system is thus much more management intensive than NSG [7, 8].

(3) Controlled Selective Grazing

Controlled Selective Grazing (CSG) is the occupation of a paddock by grazing animals until the acceptable grass species have been grazed to a stage that will ensure rapid re-growth and a high production of forage [17]. The traditional type of rotational grazing that is normally used in South Africa is CSG. The number of paddocks used for every herd when using CSG can vary from two to eight and even more than eight paddocks/herd. The grazing and rest periods are worked out in such a way that each paddock is used at a different time of the season every year. The alternative periods of defoliation and rest allows the plant to recover and grow after defoliation [7, 8].

In practice, it is difficult to classify each farmer's system, as described above. This is because almost every farmer has his own variations on the basic system and often uses a combination of different approaches. In reality, therefore, there are as many grazing systems as there are farmers. From a conceptual point of view, however, all grazing systems have five basic parameters that can be adjusted to a lesser or greater extent by the farmer, namely [8]:

- Stocking density — this is the number of animals per unit area. The most important consequence of stocking density is that it affects the rate at which plant material is removed from the rangeland and therefore largely determines how long animals can stay in a paddock.
- Grazing period — the amount of time that animals are kept in a paddock, together with stocking density, determines the degree of rangeland (or plant) utilization that takes place while the animals are in the paddock.
- Rest period — while the rest period is often determined by the grazing period, it is not so in situations where a paddock is grazed several times a year. The resting period and seasonal conditions determine the degree of rangeland recovery that will occur. The right balance between the extent of rangeland utilization and the rest period is probably the most important factor that ensures successful rangeland management.
- Herd composition — this affects the pattern of rangeland utilization because different types of animals tend to use different components of the vegetation.
- Paddock size — although not as readily adjustable as the above parameters, paddock size is an integral part of a grazing system as it determines the range of stocking densities and grazing periods that are possible.

2.3 Which Grazing System Is the Best?

Each grazing system has its advantages and disadvantages. Allegations are often made that some systems are better than others — these statements are often untested and it is largely based on circumstantial evidence and personal experiences [8]. Research has shown that there is no constant relationship between the grazing system that the farmer applies and the long-term condition of their rangeland. It highlights two key factors: (1) This indicates that no grazing system is better than another one, except for prolonged continuous grazing; (2) This shows that the management practices that the farmer apply has a greater influence on rangeland condition than the grazing system itself. Any grazing system can lead to rangeland degradation if applied incorrectly. No system is therefore better than any other system, once again except for prolonged continuous grazing. However, a number of principles are identified that can lead to long-term sustainable rangeland management. These principles, which can be regarded as the best or minimum practices, are the following [7, 8]:

- Grass plants should have the opportunity to set seed, distribute the seed and establish new seedlings. This is usually done by a rotational grazing system — in other words, when there are no animals in the paddock or area, the plants get the opportunity to rest. Rest in plants does not mean a period where nothing happens —— it is actually the time when active growth and movement of nutrients occurs. Plant rest must occur during the growing season and the rest period should be long enough to allow growth, seed formation and distribution of the seed. It is certainly not possible to rest each paddock or area within the same growing season — the grazing system must be such that different paddocks or areas in subsequent growing seasons will be rested.
- The stocking rate should be the same or close to the recommended stocking rate for the farm. Although innovative grazing systems can increase the long-term sustainable stocking rate of the farm, too high stocking rates will inevitably lead to rangeland degradation in the long run.
- The rest period between grazing periods should be proportional to the grazing pressure that was applied. If a paddock or area is grazed for a long period or it is grazed by a large number of animals, the rest period must be long enough to allow the biomass to recover, but especially that the roots of the grass plants can recover.
- Supplement feeding should be used to address mineral or energy shortages in the animal rather than to meet the fodder needs of the animal. Over-feeding with supplements has a serious negative effect on the rangeland because the condition of the animals is no longer in relationship with the condition of the rangeland.
- The grazing system must be flexible and adaptable — unexpected climatic conditions may affect the normal grazing and rest periods, and if the system is rigid, appropriate adjustments cannot be made timeously. Practically, this means that there should always be an additional fodder bank on the farm that can sustain at least the breeding stock for several months.

2.4 Is rotational Grazing Possible in Communal Areas?

The short answer to the above question is a definite **YES**! There are ample examples of rotational grazing systems in communal areas in Asia and Africa in the *Climate Smart Agriculture Source Book of the Food and Agriculture Organization of the United Nations* (2013). A few examples of rotational grazing systems that have successfully been implemented in communal areas in South Africa is that of Forbes & Trollope [19] in the former Ciskei; Tau [20] in KwaZulu Natal and Van der Pol and Jordaan [21] in Limpopo. Another example is the Debshan ranch in Zimbabwe [22]. The most important aspect of all the systems implemented in the communal areas, is that the members of the village or sub-villages of a specific communal area formed groups — in other words they grouped their animals together to form different herds. In some instances immediate de-stocking took place, whilst in other cases this process was implemented later. The grouping of the animals made rangeland management easier and the important aspect of rangeland rest was possible [19-22].

In order to achieve optimal rangeland management, it is therefore imperative that the stocking density is carefully monitored, while sound management principles, especially aimed at the grass plant, must be applied. In order to achieve the latter, it is important for the farmer to consider the growth and development of the grass plant, but especially the health of the grass roots. In the next section the focus will briefly be on the growth and development of the grass plant and especially on the roots, what their purpose is and why it

is important to allow root recovery — if not done, optimal rangeland management will not be achieved.

3. Development and Growth of the Grass Plant

Grasses usually go through four developmental stages during the growth and developmental period, namely the seedling phase; the vegetative phase; the transitional phase and the reproductive phase. Without getting bogged down in the physiological processes of each phase, it is important to note what happens during each phase [23, 24]:

- Seedling phase: Grass seed germinates when soil and climatic conditions (moisture and temperature) are favorable. The grass pushes through the soil with a single leaf and the seedling phase continues until two leaves are formed.
- The vegetative phase: In the vegetative phase the leaves develop, the growth point is pushed out just above the soil and the leaves build up energy through the process of photosynthesis. When leaf growth is complete, the reserve energy is stored in the crown tissue, growth point, roots, rhizomes and stolons. The energy stored in the growth point and roots is precisely there to facilitate regrowth after defoliation. The growth point and roots can therefore be regarded as the energy storage or savings bank of the plant.
- The transition phase: Reproduction in the grass plant is induced by the climate and the photoperiod (day length). When reproduction starts, leaf development stops and the number of leaves are determined and new leaf development does not occur. The stem parts between the nodes begin to elongate and the inflorescence lengthens in the upper leaf sheath.
- The reproductive phase: The inflorescence emerges in this phase. Pollen is released and if the process is not interrupted by defoliation, seeds are formed. No stem growth will occur if the inflorescence is still present on the grass plant.

Different types of roots are present from the first moment of germination. The main purpose of grass roots can be summarized as follows:

- Absorption: The primary function of roots is the absorption of water and nutrients from the soil. The roots provide the leaves with water and nutrients.
- Anchoring: Roots anchor the grass in the soil to prevent it from being blown away or washed away or trampled.
- Hormone synthesis: It is claimed that the roots are the main source of cytokine and gibberellin - these hormones control leaf growth and leaf development.

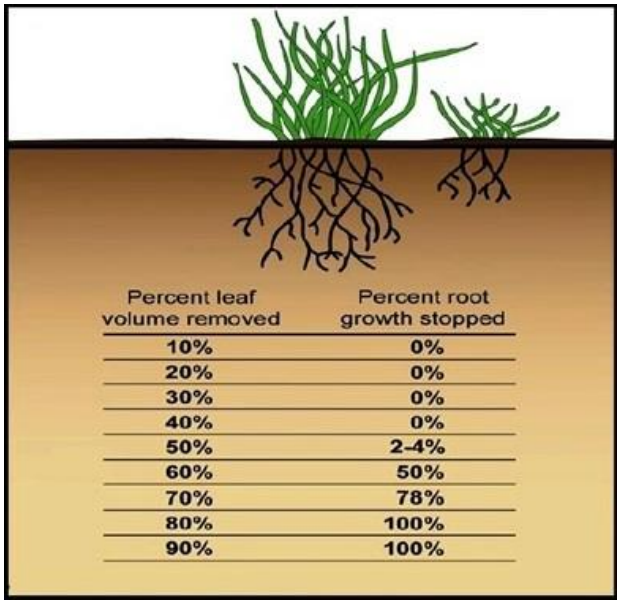
The different roots and root structures control the growth and development of the entire grass plant. The roots are often called the heart of the grass plant. Research has shown that healthy grass tufts has a root mass that is about twice as much as the above-ground biomass (Fig. 1).

4.1 What Happens If A Grass Plant Is Grazed?

As already mentioned, the green leaves build up energy through the process of photosynthesis. When the grass plant is grazed the leaf area as well as the number of leaves that can photosynthesize, decrease. However, if enough leaf material is left behind when the animals are removed, photosynthesis and regrowth will occur normally without the need to extract stored energy from the roots and growth point. However, if the plant is overgrazed, there is too little leaf material left to facilitate normal photosynthesis. To achieve regrowth in this case, carbohydrates (energy) must be extracted from the roots to facilitate regrowth. The moment this occurs, root growth and development cease for a period (Table 1).

Fig. 1 Root mass of a healthy, perennial grass tuft.

Table 1 The percentage of root growth that stops following the percentage defoliation [26, 27].



Percent leaf volume removed	Percent root growth stopped
10%	0%
20%	0%
30%	0%
40%	0%
50%	2-4%
60%	50%
70%	78%
80%	100%
90%	100%

From this table it is clear that if 50% of leaf material is removed (50% is left behind), the percentage of roots that stop growing is only between 2-4%. However, if only 10% more is removed (only 40% is left behind), 50% of the roots stop their growth. If heavy grazing is applied, leaving only 10-20% of leaf material, 100% of the roots will stop growing and develop. Studies have shown that this stop in root growth can usually be between 6-14 days, but it can even last as long as 21 days. If the grazing intensity is too high (too many animals) and/or the grazing frequency is too fast (paddocks are grazed before they have recovered), root growth can and will stop - the roots do not only stop growing, but a large percentage of roots also die off. Because little leaf material is available in this case, energy must be drawn from the roots and to a lesser extent the growth point for regrowth. Due to the cessation of growth of the roots as well as the natural mortality, less energy is available for growth and the plant develops more slowly and becomes smaller. If it is grazed again during this recovery period, this vicious cycle is repeated — in other words, even fewer roots are available; less energy for regrowth and the end result is that the vigor of the grass tuft decreases and eventually it dies. Heavy grazing also usually damages the growth point which also means that no energy is available for regrowth from this point. As already mentioned, the roots can be regarded as the "savings account" of the grass plant. With each withdrawal from the savings account, the inventory of energy becomes less and if the account is fully withdrawn, it must be closed due to insufficient funds (no energy for regrowth available — it is at this stage that the plant dies). This principle is illustrated graphically in Figs. 2 and 3.

In Fig. 2, it is clear that both root mass and above-ground biomass decrease as the grazing period becomes longer and the recovery period becomes shorter.

In Fig. 3, it is clearly shown that the vigor of the grass plant will decrease if the grazing frequency increases. The same effect will also be obtained if the grazing intensity is too high.

4.2 How Is A Healthy Grass Plant Obtained?

From the above explanation it is clear that healthy, vigorous plants can only be obtained if the plants can get sufficient rest. As already mentioned, rest in the case of the grass plant means precisely the time when active growth and development takes place. So to say that paddocks are rested during the winter does not mean anything to the grass plant as no growth occurs during the winter. It is therefore of the utmost importance that paddocks on the farm are rested alternately for a whole growing season.

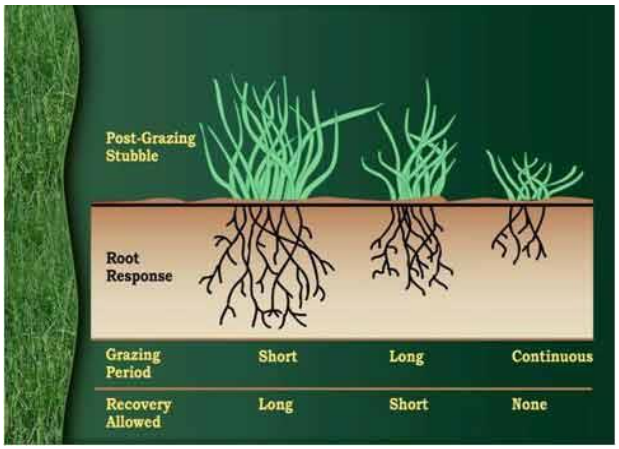


Fig. 2 Root response to different grazing periods [28].

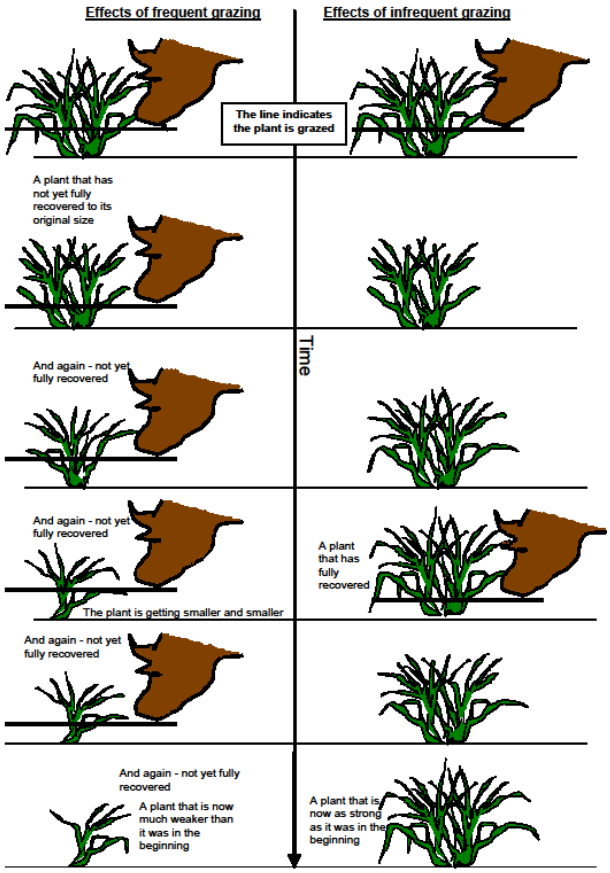


Fig. 3 A decrease in vigor of the grass plant as the grazing frequency increases [29].

The number of paddocks that are rested each year will depend on the farmer's farming setup and practices and can vary from one paddock per year to several paddocks per year. There are several alternating rest systems that can be used, for example the third rest system [30] and the fodderbank system [31].

4.3 Monitoring and Record Keeping

In order to implement an effective and sound grazing system, reliable and accurate farm maps are essential [8]. Such maps should indicate the boundaries between paddocks on the farm as well as the extent of each paddock and the location of water points within the paddock. An accurate assessment of the area of each paddock is required in order to set the appropriate stocking rates. Furthermore, since different paddocks may contain different rangeland types with different potentials, the grazing potential of each paddock should be individually assessed and the stocking rate adjusted accordingly. Allied to this should be a simple rangeland condition monitoring system. Monitoring is essential to assess changes in rangeland condition that may require stocking rates or other management activities to be adjusted. The monitoring system can involve actual measurements of the rangeland condition or it can be more reliant on other indicators such as repeat photographs taken at several predetermined sites across the farm [8]. A record-keeping system should also be in place which captures at least the following details:

- The date the livestock entered the paddock.
- The date the livestock were removed from the paddock.
- The type and number of livestock that were used.

- Any other related activities such as whether or not the animals were provided with supplementary feeding.
- Any livestock mortality that occurred while the animals were in the paddock and the suspected reason for the mortality.
- A record of the rainfall at the farm, preferably on a daily basis should also be kept. However, if this is impractical weekly or monthly records are also useful [8].

5. Conclusion

Optimal rangeland management is within the reach of every farmer. Optimal rangeland management is not linked to a specific grazing system, but rather to the amount of rest allowed for the grass plant. Optimal rangeland management is therefore done when the vegetation on the farm consists mainly of vigorous and healthy grass tufts — this can only be obtained if the plants have healthy root systems. Optimal rangeland management can therefore be obtained if:

- The grazing intensity and frequency are carefully monitored and the rest periods adjusted accordingly.
- Grass plants are allowed to rest during the active growing season. It can be obtained by:
  - Dividing the farm into paddocks/parts/blocks and then make sure that certain paddocks/parts/blocks of the farm will rest for a full year.

A good monitoring and record keeping system is in place. Monitoring is extremely important to detect changes in the rangeland condition quickly — if changes occur, this may require that the stocking rate or other management adjustments should be made.

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