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Complexity in the spatial utilization of rangelands: Pastoral mobility in the Horn of Africa

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ABSTRACT

Extensive movement is a key strategy for pastoralists to ensure adequate forage intake for livestock while distributing grazing pressure throughout the landscape. However, the complexity of pastoral mobility was overgeneralized in previous research, which often leads to sedentarization-oriented policy-making. Based on continuous GPS-tracking of cattle movement over seven months and pastoralist knowledge of mobility, we investigated spatial rangeland utilization patterns in five study sites across the Borana Zone of southern Ethiopia. By quantifying the extent of movement, density of utilization, and recursive use of rangelands, we found highly diverse mobility patterns and resource-use strategies even within a single study region. Rather than the central-place model, pastoral mobility patterns in Borana can be characterized using restrictive, semi-extensive, or extensive herding models. The research findings suggest that sedentarization largely results in compromised mobility. Thus, we recommend both intra- and inter-community coordination to reduce recursive use of rangelands and mitigate degradation.

1. Introduction

Being mobile is an important strategy adopted by millions of pastoralists worldwide to ensure adequate forage intake for livestock while maintaining rangeland ecosystem sustainability (Brown, 1971; Coughenour, 1991; Coughenour et al., 1985; Homewood, 2008; Smith, 1992). Forage quality and productivity within a single patch of arid or semi-arid land (ASAL) can vary vastly both intra- and inter-annually in response to changes in precipitation and other environmental conditions (Behnke, Scoones, & Kerven, 1993). Consequently, rather than fixed control of a specific piece of land, pastoralists in ASAL typically require flexible access to multiple pastures in well-dispersed and strategic locations in order to meet the nutritional demands of livestock and better distribute grazing pressure throughout the landscape (Marin, 2010; Turner, McPeak, & Ayantunde, 2014).

Early attempts to study pastoral mobility yielded conceptual models based on long-term field observation and ethnographic investigation (Coppock, 1994; Spencer, 1973). These models largely assumed forage distribution as the global driver of broad-scale migration, and daily herding management as the local driver of grazing pressure distribution (Coppolillo, 2001). One of these models proposed that grazing intensity is evenly distributed within a defined distance from pastoral settlements (Homewood & Rodgers, 1991) (Fig. 1a). This means that grazing intensity is uniform with regard to direction from settlement. Another model predicted that grazing intensity decreases as it gets farther away from settlement, and the rate of change in grazing intensity is uniform regardless of direction from settlement (Spencer, 1973) (Fig. 1b). In this case, pastoral resource-use patterns could be characterized by the central-place model (Coppolillo, 2001) or as a piosphere (Lange, 1969). The area near settlement is subject to heavy and recursive livestock use, thus becoming a 'sacrifice zone.' A 'transition zone' occurs farther from settlement and is represented by steadily decreasing grazing pressure. At distant locations from settlement, grazed zones gradually give way to areas which are rarely visited or influenced by livestock grazing. A third model

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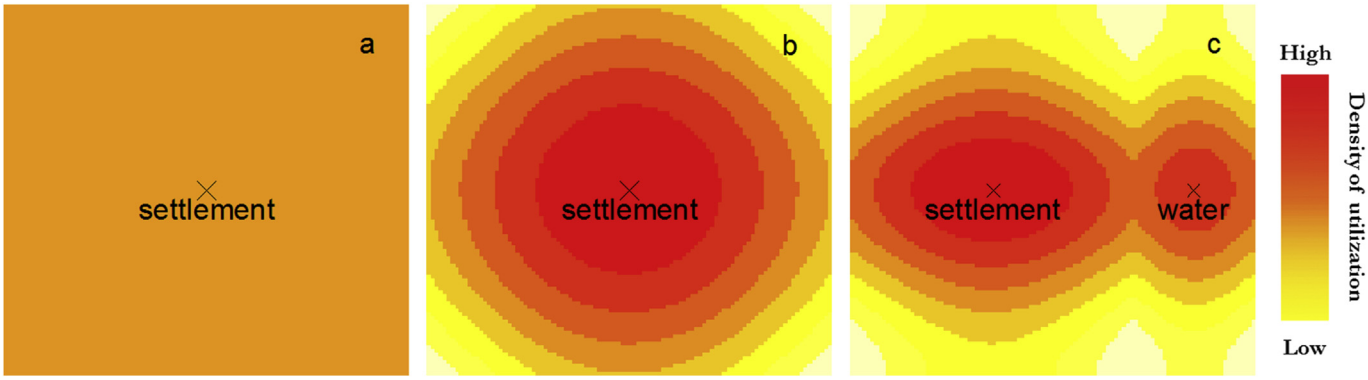

Fig. 1. Three conceptual models of pastoral mobility with distinct patterns of spatial utilization.

added environment variables such as water into consideration, and proposed that grazing intensity decreases as it gets farther away from settlement, but livestock move between the settlement and a point source of drinking water as they need to be watered on a regular basis (Western, 1975) (Fig. 1c).

By synthesizing the above pastoral mobility models, a diachronic model of grazing pressure was proposed to characterize the spatio-temporal variations in grazing pressure as a response to resource availability variations within the year (Moritz et al., 2010). This diachronic model predicted that after the rain season starts, pastoralists would first use the patches of rangelands with better forage quality and less travel cost from settlement. However, by the end of dry season, cumulative grazing pressure would be evenly distributed within their extent of movement.

The conceptual models above provided valuable insights into rangeland management and pastoral policy-making in ASAL; however, these models were largely confined to characterizing livestock herding around settlements. Empirical research suggests that pastoralists move far beyond their settlement areas in search for greener pasture, exhibiting more complex mobility patterns than described in the models above (Brottem, Turner, Butt, & Singh, 2014). For example, in the Borana pastoral system of southern Ethiopia, a mixture of home-based herding (known as *worra*) and satellite-based herding (known as *forra*) has been practiced for centuries (Coppock, 1994; Wario, Roba, & Kaufmann, 2016). *Forra* herding is a key strategy for Boran pastoralists to make use of distant under-utilized rangelands during dry seasons.

However, sparse evidence was collected to investigate extensive movement beyond settlement areas, which is commonly practiced on the rangelands in Africa and Asia (Liao, Morreale, Kassam, Sullivan, & Fei, 2014; Niamir-Fuller, 1999). Although indirect measurements derived from observations, interviews, participatory mapping, and household surveys could be used to infer pastoral mobility at multiple scales (Brottem et al., 2014; Homewood & Lewis, 1987), data collected using these approaches was usually of limited accuracy and reliability. While revealing broad-scale seasonal migration routes, details of fine-scale movement and cumulative rangeland utilization patterns can hardly be derived from such data.

Often due to the lack of sufficient understanding of pastoral mobility and spatial patterns of rangeland utilization, government entities have used partial, anecdotal, and perhaps erroneous evidence to design policies to sedentarize pastoralists and transform their livelihoods. Pastoralists are commonly accused of being collectively 'irrational' – albeit individually rational – assuming that each individual attempts to maximize livestock production from limited rangelands without considering environmental consequences (Hardin, 1968). Correcting such accusation about pastoralists requires more accurate models of pastoral mobility, in which quantitative monitoring data is crucial to reveal and predict pastoral resource-use patterns under current and projected socio-environmental conditions.

With the emergence of GPS-tracking technology and spatial analysis tools, tremendous progress has been made in the study of pastoral mobility. Portable GPS instruments were installed on domesticated animals to study their movement patterns under the free-ranging, unfenced situations typical of the African and Asian rangelands (Adriansen & Nielsen, 2002; Butt, Shortridge, & WinklerPrins, 2009; Coppolillo, 2000; Kawamura et al., 2005; Moritz et al., 2010; Schlecht, Hülsebusch, Mahler, & Becker, 2004). These efforts generated valuable information on how livestock moved within their unique contexts.

Significant shortcomings, however, still exist in the modeling of pastoral mobility. This is primarily because extensive movement behaviors (e.g. camp relocation) were rarely captured in previous studies. Short battery lifespan required frequent recapture of livestock, data downloading, and battery recharging or replacement. Intensive labor was required, and there were substantial risks to personnel who regularly followed livestock into potentially dangerous areas (Butt et al., 2009). Therefore, the collected data was generally limited in space and time. Without continuous and intensive tracking data on livestock movement, it is impossible to assess the cumulative resource-use patterns and camp relocation strategies practiced in the extensive ASAL grazing systems.

The goal of this paper is to evaluate the complexity in spatial utilization patterns by pastoralists and investigate the socio-environmental factors which drive and shape this complexity. Our research seeks to address the knowledge gaps on pastoralist extensive herding practices by using custom-built, high-performance GPS collars (Clark et al., 2006) deployed in multiple study sites to monitor livestock movement. This advanced GPS-tracking technology allowed intensive and continuous collection of livestock movement data at relatively low cost, which made it possible to examine fine-scale, cross-season movement patterns and compare how mobility strategies vary in different herding contexts. The specific objectives are to: 1) determine how and why pastoral mobility vary across different socio-environmental contexts in the Borana Zone of southern Ethiopia; 2) test the validity of the central-place model by examining the relationship between density of utilization by livestock and distance from settlements; and 3) investigate how the extents of livestock movement increase on a daily basis and their implications on recursive use of rangelands.