Original Article

Living *Off* Uncertainty: The Intelligent Animal Production of Dryland Pastoralists

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Abstract Despite important advances following the challenge to equilibrium-based models in range ecology, pastoralism is still largely seen as a coping strategy that allows herders to get along with an 'inadequate' resource base. This stance can be traced to a long-established approach in the disciplines that inform pastoral development planning (natural resource management, range ecology, animal science) to rely on analytical tools based on standard statistics and average values. However, pastoralism is better understood as a *sui generis* production system, that deliberately exploits the transient concentrations of nutrients that represent the most reliable feature of dryland environments; a system geared at maximising the production of economic value while stabilising its performance in environments where 'uncertainty' is harnessed for production. As average values and standard statistics fail to capture non-uniform distribution (relied upon for production in dryland pastoralism), they should not uniquely or uncritically inform pastoral development planning.

Malgré les importants progrès réalisés suite à la remise en question des modèles d'équilibre appliqués à l'écologie pastorale, le pastoralisme reste largement considéré comme une stratégie d'ajustement permettant tout juste aux éleveurs de survivre à partir de ressources 'insuffisantes'. Cette position trouve son origine dans une approche adoptée depuis longtemps par les disciplines qui façonnent la planification du développement pastoral (gestion des ressources naturelles, écologie pastorale, zootechnie) qui consiste à s'appuyer sur des outils analytiques basés sur des statistiques standardisées et des valeurs moyennes. Pourtant, le pastoralisme se comprend mieux comme un système de production sui generis, qui exploite délibérément les concentrations fluctuantes de substances nutritives, ce dernier point constituant la principale caractéristique des terres arides; comme un système conçu pour maximiser la valeur de la production tout en stabilisant ses performances dans des environnements où 'l'incertitude' est exploitée pour la production. Les valeurs moyennes et statistiques standardisées ne permettent pas de prendre en compte la répartition non-uniforme (sur laquelle repose la production pastorale dans les milieux arides) et par conséquent ne doivent pas constituer les seules sources de la planification du développement pastoral.

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Introduction

That the definition of pastoralism has always been problematic is a matter that should perhaps have received closer attention as the signal of a fundamental misfit between pastoralists' actual practices and the system of reference used for their analysis. The understanding of pastoralism as an economic activity has paid little attention to the most

specialised producers: those who are scattered and mobile, difficult and expensive to locate, reach, follow and keep in touch with. Instead, efforts to understand and improve 'pastoralism' have concentrated on the least specialised conditions, and often on people in economic difficulty, who appeared more easily interested in a Western approach to animal production. The consequences of this legacy can hardly be overestimated. After substantial advancement in the study of rangeland ecology, descriptions of pastoralism remain characterised by narratives of deficit: resource scarcity, difficulty to adapt, struggle against droughts, diseases and insecurity. These narratives still shape the perspectives of development and policymaking, as well as much of academic discourse. An alternative focus on the most specialised and successful dryland producers leads to a different understanding of pastoralism, calling for a reconsideration of deficit narratives and the principles behind them.

A recent challenge to equilibrium models in financial economics – from a mathematical perspective – questions the utility of analytical tools based on average values when dealing with conditions of unpredictable variability. The argument is plain and fundamental enough to have wider applicability: the 'bell-curve' models of standard statistics (Gaussian models) assume that the largest possible values in the series under analysis are either so rare as to be negligible or not too far away from the average. However, when the most likely breakdown of an average is 'asymmetric' – as in the case of systems characterised by non-uniform distribution – average values cease to be meaningful simplifications and become highly misleading. Average values are therefore inadequate to represent the behaviour of systems characterised by asymmetric (non-uniform) distribution (Mandelbrot and Hudson, 2004; a more popularised form of this argument is in Mandelbrot and Taleb, 2006; and Taleb, 2007). In this article, we argue that specialist dryland pastoralists *produce* by exploiting non-uniform distribution – in the form of what we call the 'intelligent' harvesting of unstable concentrations of nutrients on the range.

We make this general point on the basis of the literature and on primary data from our respective research on the production/breeding system controlled by the nomadic Wodaabe[1] of Niger, a substantial part of which has been published. While concentrating on this particular example of dryland pastoralism, we are aware that this approach has its limitations. The term 'pastoralism' represents a large spectrum of realities and we do not claim to embrace them all in our description. Nevertheless, the extreme operating conditions and high levels of specialisation of the Wodaabe present a magnified view of a way of using livestock and environment for production that is meaningful throughout the entire spectrum, if not always as obvious and crucial.[2] Our contribution to generality therefore consists in offering such a view as a *point of reference* for the analysis of dryland pastoralism as a system of animal production.

Within this perspective, although we describe what actual pastoralists do in real life, we only highlight the aspects of the pastoral system that, as we argue, are key for production. We refer to the key role played by mobility in enhancing production, but we are aware that there are also other types of pastoral mobility not equally related to production (Schareika, 2003b; Krätli, 2008a; IIED and SOS Sahel, 2009). Similarly, we do not claim that the 'intelligent' harvesting of unstable concentrations of nutrients on the range explains all the dimensions of pastoral livelihood. Not all what we describe does necessarily take place always in the most functional way throughout the life cycle of every herding household. Pastoralists, like anybody else, operate within complex social and political systems: insecurity, poverty, access to services, markets, social capital or development resources, they all influence decisions about production. However, when dryland

pastoralists are successful producers, they do so by exploiting asymmetric distribution, not stability and uniformity.

On the other hand, average values and models of standard statistics designed to seek out stability and uniformity as the underlying condition for capturing economies of scale are fundamental to all dimensions of pastoral development, from natural resource management to service provision. Conventional models of animal production also rely on a standardised environment.[3] Production in dryland pastoralism might therefore be at odds with some of the most basic items in the tool bags of both pastoral development planners and policymakers.

It is almost three decades since Sandford (1983) problematised the ecological paradigm in pastoral development, and Ellis and Swift (1988) suggested that pastoral ecosystems are better understood as driven by stochastic events rather than homeostatic mechanisms. Both works pointed out that pastoral development solutions that were considered self-evident were indeed dependent on a particular analytical model of ecological systems. From the new perspective, as formalised by Behnke and Scoones (1993):

> The producer's strategy within non-equilibrium systems is to move livestock sequentially across a series of environments […] *exploiting optimal periods in each area they use* […] Herd management must aim at responding to alternate periods of high and low productivity, with an emphasis on exploiting environmental heterogeneity *rather than attempting to manipulate the environment to maximise stability and uniformity*. (Behnke and Scoones, 1993, pp. 14–15, italics added)

Although this perspective combined an ecological dimension with an economic one, it was mainly the former that captured the attention. Current resource-scarcity models of dryland environments, and implicitly the explanation of pastoral mobility as a 'coping strategy', still frame unpredictable ecological variability as unfavourable to production: environmental variability is a fundamental problem that pastoralists 'solve' by moving. The current wave of claims on the increasing vulnerability of pastoralism in the face of global climate change (presumed to increase environmental variability) goes unchallenged on the basis of this assumption.[4] Deficit views of dryland environments (ultimately as *lacking* stability and uniformity) imply that agricultural production systems *must* rely on uniformity and stability. Even when these views accept that unpredictable variability is structural to dryland *ecology*, they still represent it as a disturbance as far as the *economic* dimension is concerned (that is, animal production), be it a problem to 'cope' with or a risk to be avoided.[5]

We focus on the economic side of Behnke and Scoones's argument, and follow up on its implication that environmental heterogeneity – or the 'asymmetric distribution' (in Mandelbrot's terminology) of nutrients on the range – is what dryland pastoralists rely upon for production. We look at how pastoralists produce, including human–environment interaction and, crucially, human-animal interaction in herd management. We see two advantages in this approach: first, it shifts the focus away from the many problematic implications of using ecology and natural adaptation as the key explanatory framework for pastoralism; second, it avoids the difficulties associated with defining ecosystems as equilibrium or non-equilibrium[6] as a preliminary step to understand pastoralism.[7]

This article starts from an overview of the key literature, presents the empirical evidence and concludes spelling out the crucial implications for pastoral development planning. Given our transdisciplinary perspective, our use of the literature is necessarily limited to the most strictly relevant works.

When Uniform Distribution Cannot Be Relied Upon

As is well known, dryland pasture exhibits a characteristically patchy growth pattern that, however, represents only the most macroscopic form of heterogeneity. The asymmetric distribution of nutrients applies to a whole range of scales: between ecological zones, swards, plant species, plants of the same species and even parts of the same plant. Nutrient content also accumulates and then decreases throughout the plant's life cycle (Breman and de Wit, 1983; Alimaev, 2003) and, on a smaller scale, within the 24-hour cycle (Kim, 1995; Orr *et al*, 1998; Mayland, 2000). Unpredictable precipitation in the drylands can 'start' a plant at any time of the 'rainy season', while the arrival of the dry season cycle can 'stop' it at any stage of development – therefore at different levels of nutritional value.

Despite the efforts of several range ecologists to quantify both spatial and temporal heterogeneity of nutrient distribution and advocate for its use in animal nutrition (see note 2), unpredictable environmental variability in the drylands is still commonly seen as an obstacle to pastoral production (see note 5). Roe *et al* (1998), by contrast, have described pastoralism as a high-reliability system, hence as a *sui generis* system of production, 'native' to structurally unpredictable environments and operating not by avoiding risk but by harnessing it as the very base of production. This line of thinking, that we will follow closely, invites us to conceptualise nomadic pastoralism as geared towards the exploitation of asymmetric distribution (which is prevalent) rather than seeking uniformity and stability (which is exceptional). In other words, the unstable heterogeneity of dryland environment is not an obstacle to pastoralists: it is what they produce with. As we will see, this is done by systematically targeting and intelligently harvesting the transient concentrations of nutrients on the range.

This implies that pastoralists or, better, their herds should be versed in the 'art' of feeding selectively. Strands of animal nutrition science specialising in tropical and sub-tropical regions have for a long time grappled with issues of grazing dynamics and feeding selectivity. Periodical waves of dissatisfaction with the conventional heuristics of the discipline when applied to these issues have yet to develop into a systematic challenge. For example, an early review highlights the link between heterogeneity of tropical pastures and feeding selectivity, and concludes that 'the ultimate test of any index of the nutritional value of herbage is in its relationship to animal performance' (Stobbs, 1975, p. 148). Twenty years later, the cutting-edge had not moved much further:

> grazing ruminants select a higher quality diet from Sahelian rangelands than can be predicted on the basis of pasture evaluation alone. Therefore, the foraging behaviour of the animals needs to be considered in the evaluation of Sahelian rangelands for animal production. (Ayantunde *et al*, 1999)

When the counterintuitive opportunities offered by non-uniform distribution of nutrients in the drylands are spelled out, this is done with uneasiness and often with an attempt to wrap it up in the familiar perspective: '*Although problematic*, spatial and temporal variability *paradoxically* allows animals to successfully exploit *unpredictable and low quality* rangeland environments' (O'Reagain and Schwartz, 1995, p. 16; italics added). Scholars writing on these issues as recently as 2005 point out that

> Little progress was made on the grazing ecology of tropical and sub-tropical pastures during the 1980's and 1990's, and it became generally accepted that tropical pastures only produced stemmy, low density, poor quality herbage, suitable only for low levels of animal performance […] This seems a rather simplistic generalisation of a complex problem. […] The tropical/sub-tropical

> environment is unique, requiring creative and site-specific solutions to overcome production constraints in order to realize its potential. (Da Silva and Carvalho, 2005, pp. 4, 11)

While these studies openly recognise the instability and non-uniform distribution of nutrients on the tropical range, they tend to treat feeding selectivity itself as a stable and uniform feature in ruminants, a standard response (or set of responses) triggered by different sward conditions.

Research on ruminants' feeding behaviour from an applied ethology perspective challenges the determinism of equilibrial models like the optimal foraging theory, and found that selective feeding is inextricably entangled with cognitive variables (Provenza and Balph, 1987; Launchbaugh *et al*, 1999b; Provenza, 2003).[8] Selectivity is neither stable nor uniformly distributed within species. The efficiency of competent feeders can be enhanced by its combination with other skills – for example, the experience in managing thermal stress (Brewer, 2005) – or jeopardised by external factors leading to distraction, fatigue or stress – for example, antagonistic behaviour from conspecifics, fear or traumatic events in handling, noise or smells on the range (Seabrook, 1972; Rushen *et al*, 1997; Waiblinger *et al*, 2002; cf. also for a general overview Waiblinger *et al*, 2006). A robust strand of experimental research shows that sheep, goats and cattle can be trained to feed selectively on certain plants or according to desired patterns.[9]

When the harvesting of non-uniformly distributed nutrients by non-uniformly distributed selective feeding patterns is analysed with the standard models designed to highlight stability and uniformity, problems arise: 'models predicting intake and animal performance […] based on averages […] do not cope with the structural, spatial and temporal heterogeneous nature of forage production [nor] with constraints to intake as influenced by the 'state' or physiological condition of the animal' (Hardy *et al*, 1997, p. 49).[10]

Exploiting Asymmetric Distribution

In this section, we substantiate our claims mainly with reference to the production and breeding system of the Wodaabe herders in Niger. We only touch upon those aspects of the system that are critical to our argument. The Wodaabe are a Fulfulde-speaking group of extremely mobile pastoralists found in the arid savannah zones of Niger, Nigeria and Chad. They are well known in the ethnographic literature for their lineage-based social organisation, their secluded and scattered style of life in the bush and their outstanding knowledge in the raising of their mahogony, long-horned Bororo zebus (Stenning, 1959; Dupire, 1962 and 1970; Bonfiglioli, 1981 and 1988; Schareika *et al*, 2000; Schareika, 2001, 2003a, b, 2007, and in press; Krätli, 2007 and 2008a).

Systematic Targeting: The Production Strategy

Wodaabe dryland pastoralism cannot simply be interpreted as a coping strategy for 'harsh' and 'marginal' environments. There are, of course, important elements of coping (and indeed instances of failure to cope) in Wodaabe pastoral life, but this must not distract from the fact that the Wodaabe production system is basically proactive, methodical and geared at value creation and maximisation, rather than mere survival.

The Wodaabe clearly express their production goal as maximising cattle reproduction: getting cows ready for mating (*nagge ho'osina*) and this with as short calving intervals as possible. The Wodaabe state equally clearly that this goal is to be achieved by a system

of methodical animal nutrition that optimises the animals' metabolism on the one hand and provides them with high-quality fodder resources that are selected at each point of the yearly cycle according to a long-term programme of weight building. The concern for improving animal nutrition (hence maximising weight building and animal performance) is deeply embedded in the Wodaabe social and economic organisation of herding. They critically question each pastoral decision by the maxim 'look for the better' (*raara to Buri*). In addition, they constantly compare the performance of various herds and engage in a conventionalised competition of evaluating and praising different herders' pastoral choices (*mbeefi*). The Wodaabe do not bother with the attainment of 'optimal' production targets; rather, they exhibit a context-specific understanding of herd performance, where the measure of success is relative to competing fellow herdsmen and where the limit of success is open to continuous experimentation in 'search of the better'. Nomadic movement, therefore, is not only the means by which drylands' unstable heterogeneity is put to use, it is also the experimental framework for the evaluation of the feeding value of that heterogeneity.[11]

It is important for our argument to underline the Wodaabe's proactive stance of maximising feeding quality through nomadic movement rather than just bringing their cattle to where the pasture is. When they say 'there is no grass' (*geene ngalaa*) this should not be taken literally. Grass can be plentiful, but *not* the grass that optimises the metabolism of their cattle. The Wodaabe generally move in order to reach better feeding conditions (*geene Buri toon* 'grass over there is better'). The evaluation of fodder quality rests on two sources of knowledge. First, on a permanent inspection of the animals' condition by the individual herder. The animals' coat, shape, respiration, behaviour, the colour and consistency of their faeces, as well as milk yield and taste, signal a healthy metabolism and the prospect of increase in weight. Any dissatisfaction in this regard immediately leads to herd and family moving to another place.[12] Second, appraisal of fodder quality rests on a sophisticated cultural knowledge system that facilitates prediction of what is good or bad for cattle.

As far as production is concerned, the herders decide their movements according to two general indicators: the presence of green matter and the nature of the soil. Fresh green matter (*kessum*) is seen to feed better than dry matter (*jo'oruDum*). In order to provide their cattle with green fodder for as long a period of the year as possible, the Wodaabe herders exploit regional variation of the starting and ending points of the vegetative growth cycle of grass. In eastern Niger, for example, they move in a long seasonal migration towards sandy soil areas that lie west of their habitual grazing zone in the argillaceous plains of Lake Chad. There, grass (particularly *Cenchrus biflorus*) sprouts early and quickly at the beginning of the rainy season when it is critical for the animals to quickly begin feeding on a more nutritious diet. Only later on, when the rains are well established, do the herders move to clayey soil that stores water more efficiently and hence produces more green grass and herbs even when the sandy-dune areas have already dried out.

The Wodaabe recognise the importance of soil quality to their cattle's well-being. Through the notion of 'power' (*mbaawu*), they describe and explain the fact that soils differ with respect to the nutritional value they generally produce in plants. Clayey soils are said to have more power than sandy soils because they contain valuable salts (*lamDam*). Where they are available, as in eastern Niger, they are generally preferred (except, as aforementioned, during the early dry season). A detailed analysis of the vegetative cycle of grass is very important to Wodaabe herding decisions. They value grass that has

'escaped', as they say, from the ground, so that cattle can take it in without sand (which can be fatal), but that has not yet reached the stage of 'ear emergence', as it is in that period of their development that many grass species give the best feeding result. By moving to sandy-dune areas in the early rainy season, Wodaabe herders realise the practical potential of this analysis. On sandy soil, grass (particularly *Cenchrus biflorus*) sprouts earlier within the rainy season and faster after each rain shower. The nomads thus turn the erratic distribution of rain and therefore grass to their advantage. As the rains vary spatially and temporarily, grass starts running through its vegetative cycle in different places at different times. Therefore, the nutrient content of grass does not peak and then go down everywhere at the same time, thus allowing extraction for a fairly short time span only. Rather, this peak is found in different places at different times; by 'following the rains' (*tokka duule*), the Wodaabe ensure that their cattle spend as much time as possible feeding the maximum quality of grass available.

The asymmetric distribution of rain (in time, location and intensity) and the nature of the vegetative cycle of grass are exploited in yet another form. In some places, the rains break off before the grass has completed its vegetative cycle. When it stops growing at the stage of tillering, it remains short, carries no ear and gleams reddishly. The Wodaabe consider it fodder of supreme quality and call it *kunDeeri*. During the early dry season, they explore the bush for this kind of grass and keep ready to move to get their cattle in touch with it. Although the Wodaabe, as all Sahelian people, hope for abundant rains, they appreciate the fact that the relatively low and erratic precipitation in their pastoral zone allows the development of *kunDeeri* on the somewhat elevated argillaceous plains. They say that, generally, with too much water they get only grass that is long and therefore of poor quality (the point raised in Breman and de Wit, 1983).

Herders distinguish between fodder plants according to several criteria. The most general distinction is between tree (*lekki*), herb (*leggel*) and grass (*geene*), with each category being attributed specific functions in animal nutrition. Grass is cattle's staple food (*nyaamdu*) and cannot be replaced by anything else long term. Herders distinguish, of course, between various species of grass and evaluate their suitability as feed for cattle. Soft grass with no disturbing spikes is usually sought after. The Wodaabe are aware that cattle eat more (that is the herders' goal) when they like what they feed on. Therefore, the herders are always seeking to stimulate their animals' appetite by leading them to fodder that, in their experience, the herd will particularly appreciate (the herders talk about favoured fodder with reference to 'tastiness' and to how much the animals look 'at ease' when feeding on it). They prefer certain species for these characteristics and target them consistently. Moreover, they enhance feeding performance by avoiding half-dry grass during the rainy season, or pasture soiled or malodorous from cattle droppings. Browse from trees is considered a tasty supplement (*DahatorDum*) to the main diet of grass. The Wodaabe compare it to the sauce that accompanies the humans' main staple of millet porridge. *Salvadora persica* (*kasassi*), *Cadaba farinosa (karatiiyel)* and *Maerua crassifolia (senseni)* are described as very interesting *DahatorDum* species. The absence of such complementary trees, even in an otherwise abundant dry grass savannah, is regarded as a critical shortcoming (cf. Stobbs, 1975, p. 144 on the need for nutritional supplements for grass).

Herbs are seen to serve various critical functions (although like trees they are not by themselves a replacement for grass). In the early rainy season, herders look for leguminous herbs, notably *Zornia glochidiata (dengeere)* and *Alysicarpus ovalifolius (gadaji'irehi)*. They attribute to these two herbs the quality of 'fixing' the animals after the deprivations

of the dry season. The late rainy season brings a number of herbal plants such as *Indigofera hochstetteri (jaa'oomaahi)* to which the Wodaabe attribute good milk production and fattening the cattle. This herbal plant can help to get cattle over a period when good grass is becoming scarce. Other highly valued herbs are *Cucumis melo (yamBuruuwol)*, *Heliotropium ovalifolium (yaharehi)*, *Ipomoea verticillata (amaseekel)*, *Ipomoea* spec. *(yagalawol)* and *Ipomoea* spec. *(buluuwol)*.

On the basis of a profound knowledge system, on permanent experimentation, on an imperative to look for the better and on extreme spatial mobility, the Wodaabe manage the dryland environment in order to turn its unstable heterogeneity of plant growth into a resource for their cattle. However, these cattle must be *capable* of making efficient and reliable usage of the opportunities offered by the herd management system. This capacity is far from being naturally given, as we show in the next section.

Intelligent Harvesting: Breeding Functional Behaviour

The herders explore the range and make decisions on timing and direction of movements. However, these decisions are made on the basis of feedback from the animals: a herder's past experience of their performance in certain feeding conditions (type and combinations of fodder plants and possible disturbances), as well as present observation of changes in the animals' conditions. The efficient targeting of transient concentrations of nutrients therefore relies on human–animal interaction.

This dimension, human–animal interaction, is also critical to what we have called 'intelligent harvesting'.[13] While efficient targeting involves reaching the most nutritious patches at the best time, intelligent harvesting is the capacity to leave, once on target, what fodder is unnecessary or undesirable to engage with. It is effective micro-operational aiming as opposed to low-discernment, large-scale engagement. The latter strategy, of course, is more convenient in the presence of uniform distribution of nutrients. But in the case of non-uniform distribution, a good diet is a balance between what is eaten and what is not eaten: the Wodaabe want their animals to eat *only* 'the right things' and leave the rest. As we know from the ethological research on feeding behaviour in ruminants, this requires a sophisticated selectivity that is not granted, but must be learned and is subject to be impaired by the operating conditions.

A system to secure intelligent harvesting

By timing, directing and monitoring the movement of the herd on the range, the herders can engineer their animals' experience of the ecological environment in order to maximise opportunities for selective feeding and minimise disturbances. Ecological opportunities are maximised by exposing the herd to the most favourable feeding conditions for the longest possible grazing time. Minimising disturbances ensures that opportunities can be taken advantage of most efficiently.

Stress from external factors can inhibit an animal's capacity for feeding selectively and for learning to do so.[14] It is therefore crucial to an animal nutrition strategy resting on intelligent harvesting, that stress-triggering events be reduced to a minimum. The Wodaabe do this by influencing the social structure of the herd. This aim is already inbuilt in their cattle-naming system (shared across all Wodaabe clans). The Wodaabe name all newborn calves (males and females) after their mothers and manage them accordingly, leading to an organisation of the herds into matriarchal lineages, a structure that keeps dominant-subordinate relationships stable.[15] Sires are castrated or marketed

as soon as they start fighting. The system of the calf-rope, where the calves are attached every night always in the same relative position, habituates pairs of animals to one another. Social bonds between calves are also promoted by separating them from their dams for a few hours per day from less than a month after birth.[16] The Wodaabe openly refer to preferential relationships between cattle with the same word (*higo*) used for human friendship. Favouring social bonds within the herd works towards improving herd nutrition, as both the practice of selective feeding and the generation and transmission of feeding competence are favoured in herds with a stable and well-developed social structure.

With regard to minimising stress from human handling, the most obvious way is to be gentle. The Wodaabe herd management system is characteristically 'soft', preferring persuasion and habituation to coercion. Management practices are very close to patterns of social behaviour that ethologists have found among feral cattle. Examples of this would be leading the animals from the front as a group (when herding) rather than threatening them from the rear, or disciplining an animal by hitting it on the horn (rather than the body) as another cattle would in asserting rank.[17] Indeed, the Wodaabe go well beyond gentle handling, managing to turn stress itself (the propensity for it in their cattle) into a resource for production. Their exceptionally shy and alert Bororo zebus are also known for their characteristically selective attachment to their human household (the attitude called *geeti*). As a result of this combination of factors, the herds of the Wodaabe really only relax in the presence of their own herder. Increasing the *geeti* attitude within the herd (something done through both selection and particular management practices) makes the intensive human monitoring, characteristic of the Wodaabe animal nutrition strategy, not only possible, but sought out by the animals themselves in order to calm down.[18]

Selection (and more generally the breeding system) is also important to securing the required feeding performance. The Wodaabe actively seek out particular morphological, physiological and cognitive features in their animals. They strictly control animal reproduction (near 100 per cent of births) through selective mating based on memorised matrilineal genealogies (feeding competence being largely learned from the dam). The breeding system, however, is not aimed at maximising a single production factor or a particularly productive lineage. There is culling within lineages but not selection between lineages. On the contrary, there is deliberate effort to secure a variety of lineages within the herd. The breeding focus is on round performance over time, meaning a cow's capacity to thrive year after year generating a strong line of descendants. Lineages that have shown reliable performance, thriving within the system for several herding generations (*na'i iririiji*) are considered of particular value.

The Wodaabe networks of breeders are careful to maintain the continuity of these lineages within the cattle population under their control. It is worth noting, however, that these special lineages are valued because of their continuity of performance and not for reasons of purebred origins. Although *iririiji* lineages are always Bororo, they can in principle begin even with non-Bororo cows. To find *iririiji* lineages bearing names that the Wodaabe only give to cattle of different breeds – for example betraying a distant matriarch from the Azawak breed – is not uncommon. The focus on *na'i iririiji* is evidence of the Wodaabe's effort to breed for reliability in overall performance, and the key to reliable overall performance within their production strategy is intelligent harvesting. Thus, we can say that the Wodaabe ultimately breed their Bororo zebus for reliability in the complex task of intelligent harvesting.

Selective feeding patterns specific to the production system

The differences in livestock feeding patterns across pastoral production systems can be macroscopic even when they operate within the same ecological settings. The difference in feeding patterns between the Bororo herds kept by the Wodaabe and the herds of Azawak zebus kept by the Touareg is a case in point.[19] The Azawak are well known for 'eating anything' unselectively, whereas the Bororo (from the herds of the Wodaabe) are known to be exceptionally selective. According to both Wodaabe and Touareg herders, while the Azawak would graze all the grass from a sward, the Bororo would only lightly browse through it, picking the best bites.[20] The Azawak's poor attitude for selectivity – undiscerningly docile with anybody but unattached to the herder (lack of the *geeti* attitude) and unselectively feeding on anything instead of focussing on the most nutritious parts of the range – is at the root of the Wodaabe's limited appreciation for these animals.[21]

Differences in feeding patterns can be significant even between herds produced within the same breeding network. Among the agro-pastoralist Peul in the south of Niger, some herds of Bororo can put on weight on the rainy season pastures in the north even during the cold dry season, but others cannot (despite being animals from the same breeding population, from the same villages and even from the same extended families). The herders themselves explain this phenomenon by saying that in order to gain weight on the northern range after the dry season has started, the cattle need to be 'accustomed' to feed on it (Krätli, 2008b).

Differences in the feeding patterns (within shared bandwidths of functionality) are acknowledged by the herders as part of what distinguishes one lineage from another. The Wodaabe's acute awareness of the characteristics of the environment they take their animals to feed in is focussed on the nature of their animals' interaction with it. This interaction is closely and constantly monitored through a number of indicators, for example, the organoleptic properties of their milk (susceptible to changes in a cow's health and diet). Although the Wodaabe link milk production to the influence of the sire, the quality of the milk is considered specific to the matrilineal lineage.[22] The Wodaabe are profoundly aware of the link between the qualities of milk in their cattle and the animals' diet. They know, for example, that the consumption of certain fodder plants at a certain stage of development make the milk taste good, while others give it a bad smell, some make it thick, some frothy, some thin, and so on.[23] All statements about differences in the quality of milk between animals (for example, between the Bororo and Azawak breed or between different Bororo lineages) indicate an underlying awareness of both breed-specific and lineage-specific characteristics in diet preferences and eating behaviour. They also express an intimate link between the 'breed superiority' granted to certain cattle lineages and their performance as feeders under Wodaabe management conditions.

Animals can be actively trained to feed on certain plants, but the most reliable way of securing feeding competence within a herd is by aligning new cattle with a group of animals that are already competent, ensuring that new arrivals have plenty of opportunities to learn from 'veterans'.[24] The Wodaabe allocate one or more heifers to a newborn child in order to constitute the initial set of matriarchs of the child's future herd. These allocated cattle lineages remain in the herd of the father and, ideally, grow into his own viable herd, inheriting from the father' herd both social structure and competence (feeding competence but also, for example, the knowledge of the territory).

To sum up, the Wodaabe production system is geared towards the tracking and exploitation of asymmetric distribution (of plant growth but not only). Methodical exploration

of the pastoral landscape by direct inspection precedes each move. The herd is moved on as soon as the next pasture area available is qualitatively better than the one they momentarily use (later on in the seasonal cycle, the once abandoned pasture area can again become 'first' choice in relation to others; that is why the nomads are monitoring and moving through the range constantly). Through close and constant monitoring of grazing conditions, the herders direct their animals so that they can get timely access to short-lived concentrations of nutrients through combinations of fodder species that, by experience, are known to trigger in those very animals comparatively high intake. The Wodaabe are aware that their system relies on the presence in their herds of particular sets of skills for feeding efficiently in conditions of asymmetric distribution of nutrients (what we call 'intelligent harvesting'). They are also aware that behavioural patterns functional to intelligent harvesting are substantially acquired (enough at least to make the difference between putting on weight or losing it on the same range, everything else being the same). Key aspects of their breeding system and herd management practices are functional to acquire, foster and preserve such patterns in the breeding population.

Conclusion: Beyond Planning With Averages

Using the example of Wodaabe production/breeding strategies, where a high level of specialisation makes our point particularly visible, we have argued for the specificity of dryland pastoralism as an agricultural production system that exploits asymmetric distribution rather than stability and uniformity in the environment.

This argument rests on two points: (1) the analysis of relevant aspects of Wodaabe pastoral system showing how production is centred on the exploitation of asymmetric distribution; and (2) the critique of Gaussian models showing that they are inadequate to analyse phenomena characterised by asymmetric distribution. The first point is supported by our empirical data. The second point is based on the literature that highlights the limit in the applicability of Gaussian statistics (a critique from a mathematical perspective and extraneous to the debate over qualitative versus quantitative methodologies). While we draw attention to its relevance for dryland pastoralism, we limit our claim of applicability to the analysis of processes that rely upon asymmetric distribution: prosperous dryland animal production does, but not all aspects of pastoral behaviour do.

The most straightforward implication of our argument is the problem of designing pastoral development solutions with analytical tools that highlight stability and uniformity (that is, what can be least relied upon for production in the drylands) and ignore asymmetric distribution as disturbance (that is, what can be most relied upon).

As we have seen, asymmetric distribution does not only concern the unstable concentrations of nutrients on the range, but many crucial aspects of the production system itself. Herds, of course, are asymmetrically distributed across the range. Mobility is asymmetrically distributed over the year and over the longer period including a drought event. Functional performance (as a result of intelligent harvesting) is asymmetrically distributed across cattle lineages and within the breeding population, as well as over time, in the life cycle of a herd/herder as a result of changing composition at different stages of development of because of substantial shock-driven loss of animals through death or forced sales.

Tropical animal nutrition science has made some progress towards the understanding of animal–environment interaction with regard to selective feeding, but so far short- and

long-term human–animal interaction and the economic role of man-made selective feeding patterns – and the broader combinations of functionality behind what we call 'intelligent harvesting' – have remained beyond the horizon of pastoral development. Analytical models relying on uniformity and stability are dominant in so many academic and administrative contexts that it is difficult even to find a cognitive space for accommodating a reality that escapes their power of representation.

A framework for conceptualising models of production working with (and exploiting) non-uniform distributions has been provided by the analysis of critical infrastructures requiring high reliability (for example air traffic control or electrical grid systems). Pastoralism itself has indeed been described as a high-reliability system (Roe *et al*, 1998). This approach is useful in showing that a production system does not need to work with uniformity and stability (that is, fit an equilibrium model) in order to be 'modern' (be it in the sense of 'rational' or 'technologically advanced'). As long as their specific requirements are respected, high-reliability systems can be modern and perfectly integrated into the market economy.

Recently, the focus of this research has shifted towards high-reliability *management*, following new findings on the crucial role of real-time operators in securing reliability (Roe and Schulman, 2008). More than the early formulation of 'high-reliability pastoralism', this new focus on the management of high reliability can provide a relevant entry point towards the development of analytical and planning tools that are more in tune with the operational reality of the herders.

High-reliability systems are fundamentally different and work according to different sets of rules from more familiar models that depend on stability and uniformity. They escape the standard notion of efficiency (production/cost ratio) as reliability cannot be traded for money. The familiar rationale of streamlining the system in order to make it more efficient does not apply, as reducing reliability in order to reduce costs leads to incalculable costs at the first system failure. Therefore, 'successful reliability management focuses less on safeguarding single-factor performance than on maintaining a set of key organizational processes within acceptable bandwidths' (Roe and Schulman, 2008, p. 159).

As high-reliability systems are largely real-time operations, they depend chiefly on management. There is a dimension of high-reliability management that is critical to the system's existence and yet that unavoidably escapes design: the best design cannot account for all that makes the system work. One important consequence is that when policymaking and macro-design are extended to regulate all areas of the system (a command-and-control approach), this effectively undermines the system's capacity to work. This is most likely to be the case also for pastoralism.

The use of average values applies to most of the common loci of pastoral development, from mobility and land tenure to water management, destocking/restocking, and drought early warning systems. We are not suggesting that pastoral development planners and policymakers should (or could) stop using average values and standard statistics. However, the risk of grossly misleading analysis following from the routine use of these tools is potentially very costly. For once, because they build into any pastoral development analysis the implication that agricultural production systems must rely upon stability and uniformity. To the extent to which pastoralism does not (because instead it exploits asymmetric distribution), pastoralists are excluded from the category of producers by the analytical framework that supposedly targets them for development interventions.

It seems pertinent, therefore, to foster the awareness of this issue, recommending specific caution to those operators whose profession calls for the use of statistical tools, and raising a permanent warning flag for all pastoral development analysts. That a model for analysing dryland pastoral production as a system relying on asymmetric distribution is not yet fully developed does not make it reasonable, or acceptable, to carry on unquestioningly with the application of analytical tools designed to measure stability and uniformity.

Notes

1. Implosive consonants characteristic of the Fulfulde language are conventionally given as uppercase letters. For the sake of readability, we have not applied this rule to the spelling of the frequently used name 'Wodaabe', which should be read as 'WoDaaBe'.
2. There is a great variety of agro-pastoral systems where peak animal performance achieved though extreme mobility is traded in for the opportunity of growing field crops. In relatively good years, the generally smaller productivity of the herd (for example, Amanor, 1995) is balanced by the fact that no or few animals have to be sold for buying food. Prolonged droughts or increased environmental unpredictability would rapidly and dramatically turn the trade off in favour of more specialised pastoralists.
3. Although we back up this generalisation with regard to the models that appear to inform policymaking and mainstream pastoral development thinking, we acknowledge the important exception of a substantial strand of research on rangeland heterogeneity using the stratification of multiscale diversity in fodder resources and the effort to develop models based on livestock feeding behaviour (Boudet, 1979, 1984; Breman and de Ridder, 1991; Hiernaux *et al*, 1994; Tongway *et al*, 2001; Ayantunde *et al*, 2009; Hiernaux *et al*, 2009). We are grateful to Pierre Hiernaux for drawing our attention to this work.
4. For example, most of the papers presented at the conference 'Pastoralism and Climate Change Adaptation in Africa', 25–28 May 2010, Egerton University, Kenya (http://www.ccaa.iccamnet.org/index.html).
5. On the survival and adaptation of risk-aversion heuristics even within pro-mobility perspectives in pastoral development, see Roe *et al* (1998).
6. See Sullivan and Rohde (2002) for an excellent analysis of this issue and Vetter (2005) for a review of the debate.
7. The understanding of pastoralism through ecological lenses is so deeply entrenched in the history of pastoral development, that it proves very difficult for operators not to drift back into old habits even when acknowledging the relevance of the paradigm shift introduced by the 'new range ecology' (see Hogg, 1997). This is even more important today, as concerns for climate change are granting new authority to ecological heuristics of pastoralism (old and new orthodoxy).
8. Provenza and Cincotta (1993, p. 78) pointed out that: 'Functional models (e.g. optimal foraging theory) […] do not […] explain empirical observations such as why: 1. individuals within species select different kinds and amounts of forages […]; 2. wild and domesticated herbivores over-ingest plants that contain toxins […]; 3. herbivores do not necessarily select foods of the richest nutritional quality (e.g. most energy-rich foods) when given a choice'.
9. For example Banner (2008). Dozens of studies and applications of this kind have been carried out by the research and outreach program of the School of Range Management at the Utah State University (http://www.behave.net/projects/index.html).
10. Current work in tropical animal nutrition openly acknowledges the inadequacy of 'traditional and simplistic view of production, in which control of the grazing process is made by means of fixed stocking rates, herbage allowances, grazing intervals and grazing methods' (Da Silva and Carvalho, 2005, p. 11).
11. To avoid misunderstanding, we wish to underline the fact that pastoral mobility is not entirely explained by the ecological aspects of raising animals in arid environments. Research on the Wodaabe substantiates (Stenning, 1959; Bonfiglioli, 1988; Schareika, 2003b) the abundant

literature on the social and political motivation of nomadic movement (for example Gulliver, 1975; Burnham, 1979). Our descriptions of nomadic movement, however, are no ideal types. They are based on detailed observation of Wodaabe real-world behaviour. We would also like to remark that social and ecological considerations in nomadic decision making do not simply correspond to different choices of movement. *Within* a general choice of movement that aims to avoid, say, requests for taxpaying, there will be room for further choices that target at optimising animal nutrition.

12. Herders are well aware of the energy costs of mobility. When the animals are weak, at the end of the dry season, and the returns expected from improved nutrition through mobility are carefully balanced against these costs. Even so, whenever possible, the herders invest in feed (bought with money from the sale of livestock) in order to give their animals the strength to move to better-quality pasture. That mobility is part of a broader strategy of reliable production, is also evident from the fact that herders discuss at length the danger of getting 'locked' into areas of dry season pastures that, if initially attractive, might remain isolated and therefore hinder or even prevent further movement.
13. This concept of 'intelligent harvesting' refers to effective targeting of nutrients and carries no implication of a *naturally* benign influence of grazing. On the other hand, in systems geared towards exploiting small and short-lived concentrations of nutrients, the productivity of the animals increases with feeding selectivity and decreases with indiscriminate biomass intake. It follows that, at its maximum level of productivity, specialised dryland pastoralism can be expected to be *inherently sustainable*.
14. Stress associated with management practices, and even with particular stockpersons, can severely abate feeding motivation and learning ability, slow down growth, interfere with reproduction, reduce the yield and quality of milk and increase the animals' susceptibility to disease (Seabrook, 1972; Knierim and Waran, 1993; Hemsworth *et al*, 1996; de Passillé and Rushen, 1999; Breuer *et al*, 2000; Lensink *et al*, 2000; Pajor *et al*, 2000; for a recent overview, see Waiblinger *et al*, 2006). There is also evidence that stress can spread along social structures. In the presence of stressed conspecifics, for example, both the heifers' feeding behaviour and their capacity for learning have been found to be inhibited (Boissy *et al*, 1998; Bouissou *et al*, 2001).
15. The social organisation of cattle in feral conditions is based on clusters of small matriarchal families interconnected by preferential relationships between their members. Social interaction is ordered by dominant-subordinate relationships and by preferential relationships. As dominance relationships among adult females are very stable and long-lasting, aggressive behaviour is rare (Reinhardt and Reinhardt, 1981; Lazo, 1994; on African buffalo, cf. Prins, 1996, and Sinclair, 1977).
16. Studies of calf–dam separation for artificial weaning with calves of 8–9 months showed that 'such abrupt weaning seems to increase temporarily the social motivation since the weaned animal strengthens bonds with peers' (Boissy *et al*, 2001, p. 90).
17. As a way of reducing productivity losses from stress, authors writing about animal production in western settings recommend handling practices designed to imitate 'species-specific' behavioural patterns (Grandin, 1987; Seabrook and Bartle, 1992; Seabrook, 1994). The affinity of this approach with aspects of cattle management among the Wodaabe is evident. Waiblinger *et al* remark that the reliance on 'species-specific' patterns is what 'may provide the basis for the success of Fulani herdsman in the control of cattle' (2006, p. 191).
18. The propensity to selective attachment (*geeti*) is one of the most appreciated features in reproduction bulls. The *geeti* attitude is further strengthened artificially by separating the calves from their dams for a few hours per day (the afternoon) well before weaning and socialising them into the human household through interaction with children (who water, groom and de-tick them). Boivin *et al* (1992) note that calves' compensating drive to socialise, following calf–dam separation in weaning can be exploited for habituating them to interact with humans.
19. This difference directly reflects the lower degree of specialisation (as cattle keepers) of the keepers of the Azawak breed, thereby confirming our description of 'intelligent harvesting' as the production strategy peculiar to specialised dryland pastoralism.
20. A French veterinarian, writing about the browsing habits of Bororo herds in Cameroon, noticed that 'foraging is so selective that at the end of the season the animals are in the grass up to their bellies' (Brouwers, 1963, quoted in Boutrais, 1995, p. 281).

21. This does not stop them from purchasing Azawak cows when necessary, developing new Bororo lineages from them by systematically cross-breeding the females with top-quality Bororo bulls.
22. In conditions of relative prosperity, herders have been known to indulge the passion for refined milk degustation, to the point of exclusively drinking the milk of particular lineages (cf. Bocquené, 1986, p. 40).
23. Cattle who have fed on certain plants are said by their herders to produce a milk with characteristic bad smells (for example, *pottalhi*/*Crotalaria podocarpa*) or unpleasant tastes (for example, *gajalol*/*Panicum turgidum*). In contrast, after foraging on *nyaanyataare (Peristrophe bicalyculata)* or *ndiriiri (Sporobolus festivus)*, milk is known to take on a characteristic good taste. Grazing on *tuppere (Tribulus terrestris)*, particularly after its early stage of development, makes milk watery and low in fat, while grazing on *nguDe-nguDeeri (Dactyloctenium aegyptiacum)*, *saraho (Aristida gracilis)* or *(Gynandropsis gynandra)* makes it thick and rich (Bonfiglioli, 1981).
24. The Gabbra/Boran in Kenya train camels by providing them with cuttings when they are still very young: 'Animals will feed on what you taught them. Camel calves [for example], before they are being released with the larger herd, they are being fed at home. So when they are released to the field, they will go for the place that you taught them while they were in the enclosure. If you feed them on the other grass, they will look for that once they are released. If you feed them on leaves, they will look for leaves' (contribution of Molu Kulu Galgalo, Kenya, The University of the Bush, 23–27 March 2009, organised by DFID Democracy Growth and Peace for Pastoralists project, supported by the Oromia Pastoralists Association, Oromia State, Ethiopia).

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