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Unlocking the Agricultural Potential of Manure in Agropastoral Systems: Traditional Beliefs Hindering Its Use in Southern Ethiopia

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Abstract: Manure is often considered a valuable resource for improving productivity in semi-arid tropics. This paper investigated agropastoralist knowledge of the use of manure and barriers that limit manure use in Borana, southern Ethiopia. The potential and actual amounts of manure available on-farm and its relative economic value were estimated. Yield response to manure application was also quantified. Data was gathered using on-farm surveys, focus group discussions, key informant interviews, field observation and on-farm experiments. We found that an enormous amount of manure with substantial fertilizer value and economic benefit had accumulated over the years in studied households in Borana. Our analysis revealed that, on average, more than 74 tons of manure containing 667 kg nitrogen (N)–more than five times the current requirements–had accumulated per farm. This manure has an economic value, in terms of N supply, equivalent to ETB (Ethiopian Birr) 16452 (US$802). On-farm trials showed that a considerable scope exists for increasing the yields of these marginal lands by using manure. However, because of the traditional beliefs and associated practices, which have prevailed for centuries in the community, this valuable resource is left unused. Having identified the link between traditional beliefs and non-use of manure, the paper sets out possible areas for intervention.

Keywords: non-use of manure; traditional beliefs; yield response to manure application; economic value; agropastoralists; southern Ethiopia

1. Introduction

This study was conducted in Borana, which is a lowland semi-arid region of southern Ethiopia. The area is largely inhabited by the Borana, a semi-nomadic people whose main economic activity is based on a combination of extensive livestock production and grain cultivation on small plots [1] Cattle comprise the largest share of livestock biomass and are the most highly valued animals in the area. They are a symbol of abundance, of social status and of community influence [2] while small ruminants are raised for cash income and meat [3]. Crop production in Borana is increasing in importance owing to human population growth, the falling availability of grain and increased demand, and frequent droughts which make livestock rearing challenging [2,4]. The Borana cultivate the land located in close proximity to their "olla"–a collective residential unit where extended families of close relatives reside [1].

Crop farming in Borana primarily involves cultivation of maize, wheat and "teff" and perennials such as sugarcane, banana and *Moringa stenopetala*. Yields are very low because of drought, floods and low inherent soil fertility [5,6], thus, improvement of soil fertility is essential to attain the desired levels of crop yield. Unfortunately, due to various constraints, there is no use of external inputs (e.g., chemical fertilizer); low input agriculture has been implemented in this part of Ethiopia.

The challenge in such drought-prone production environments is to enhance crop (both food and forage) productivity while preserving the sustainability of the land [6]. A feasible option friendly to the producer, soil and environment is needed and cattle manure, hereafter referred to as manure, is one possible option [7,8].

The merits of applying manure to depleted, low fertility and marginal soils has received a wealth of attention in the developed world [9] and the developing world [10,11]. Manure increase yields of crops and forages, and can sustain crop-rangeland integration in semi-arid sub-Saharan Africa (SSA) [12]. In many farming systems of SSA where fertilizer use is low, manure has been utilized as a valuable nutrient source for crops and this trend will most likely continue [13,14]. Because of the low cash requirements, manure is more affordable for poorer households than mineral fertilizer [8,12]. It is also clear that in resource-poor farming systems, the importance of manure will increase as more land is brought under cultivation [12,13]. However, despite all these merits, as a consequence of traditional beliefs that prevailed for centuries in the community, there is no tradition of using manure in Borana (this report). Farming systems and resource management practices in the Borana is strongly influenced by their indigenous religious beliefs and practices [15].

However, to our knowledge, no studies have been conducted on the attitudes, cultural perceptions and beliefs concerning manure in Borana, southern Ethiopia. Furthermore, no attempts have been made to investigate the barriers preventing manure use in the area. Moreover, the benefits of using manure as fertilizing material have not yet been investigated in semi-arid farming systems. Manure-based research in Ethiopia has been concentrated in medium to high rainfall areas of the country [16,17]. Even when such studies have been carried out, they have mainly focused on the availability and quality of manure and its effect on crop production. However, social and economic process, the knowledge or awareness about this resource, and farm-related features can influence the production, use and management patterns of manure in farming systems [18]. A growing body of literature has demonstrated the positive effects of manure application to different crops in agroecosystems across SSA [18]. Against this background, this study was conducted with the following objectives: (i) to assess the status of manure utilization and management (disposal, storage and handling), (ii) to assess agropastoralists' knowledge about manure use and barriers constraining its use, (iii) to quantify the potential and actual amount of manure produced, manure nutrients generated and its relative economic value, and (iv) to investigate, through on-farm experimentation, the effect of manure on maize yield.

This study is meant to inform scholars and practitioners through a quantitative and qualitative assessment of why manure is not used and its potential value in agropastoral systems of southern Ethiopia. Furthermore, by examining yield responses to manure, this study makes a contribution to the literature on the agronomic effectiveness of manure as a source of nutrient for maize production in semi-arid agropastoral setting in Ethiopia.

2. Methodology

To address its multiple objectives, this study applied a mixed method approach. Combining qualitative and quantitative methods provides a better understanding of the research problem or issues of concern than either method alone can provide. A combination of the two approaches is also essential, as each serves different but complementary roles within the overall research design [19]. The study has combined farm survey questionnaires, focus group discussions (FGDs), key informant interviews, field observation and on-farm experiments to determine the effects of manure on maize and stover yield.

2.1. The Study Site

The study was conducted in Yabello district of the Borana zone located in southern Ethiopia. The district was selected purposively as being representative of the extensive agropastoral farming systems of southern Ethiopia. The study area has a semi-arid climate with a highly unpredictable bimodal rainfall pattern [1,20], and an absence of permanent surface water [1]. Average annual rainfall at the study district during 2001–2015 ranged between 412 to 873 mm (with an overall average of 596 mm). The area is prone to periodic droughts [21]. The dominant soil types are shallow and sandy loam soils and Vertisols. The latter are restricted in valley bottoms, low-lying plains and on flat surfaces while upland soils occur elsewhere [1]. As in many parts of semi-arid eastern Africa, soils of the study area are regarded as having low inherent fertility [5]. However, according to Coppock [1], bottomlands and other sites with impeded drainage have better fertility and water holding capacity than soils on uplands. Animals graze freely on communal rangelands during the day, and are kept in kraals during the night. Though livestock production is the dominant farming practice, the pastoralists have gradually taken up crop farming since the mid-1980s drought [1], and crop cultivation is now expanding in valley bottom sites across the district, not merely for subsistence, but to diversify household income (see Section 3.1. for detail).

2.2. Field Methods

The first study was an in-depth farm survey of agropastoral households of varying resource endowment to assess manure use and its management, identify farming orientation, farm characteristics and land use practices. These variables were collected using questionnaires aided by FGDs, unstructured key informant interviews and field observation. A multi-stage random sampling technique was employed to select the samples. In the first stage, one “kebele”, the lowest administrative unit, was selected purposively based on its production orientation (i.e., widely known for its mixed crop–livestock farming practices). In the second stage, the households (159) in the selected kebele were grouped into permanent (93) and opportunistic (66) agropastorals. In this study, permanent agropastorals were defined as households where the main priority of the household head is crop-related activities, while herding is the responsibility of family members, particularly children. In the opportunistic agropastoral group, the household head’s priority is livestock herding, while family labor and sometimes shared or hired labor is usually used to manage crop fields. Accordingly, 30 households were randomly selected from the list of all the households permanently engaged in mixed crop-livestock production at the third stage. As our attention was focused on the value of manure in relation to crop (food and forage) production in the agropastoralists systems, opportunistic agro-pastoralists were not included in the study. Key informant interviews with the kebele manager and extension agents were conducted to identify and categorize all the households engaged in crop farming. For analytical purposes, studied households were categorized into three resources groups based on cattle holding: resource-poor (0.7–14 tropical livestock units, TLUs), medium (14–21 TLUs), and resource-rich (above 21 TLUs). Cattle were considered the most important indicator of wealth status in the area. Nine of the 30 households were chosen for the on-farm manure measurement and nutrient analysis study.

2.3. Procedures to Estimate Manure Production

Analysis of cattle manure production was conducted in two ways: potential manure production estimation based on the relationship between animal live weight and excretal output, and direct manure measurement that is available in the farm. In theory, the amount of manure to be produced was estimated by multiplying the number of cattle with the assumed fecal output per day. Accordingly, we used the live weight and excretion figure of Fernandez-Rivera et al. [22], who assumed that cattle in semi-arid areas of the Sahel produce 0.8% of its live weight as fecal dry matter in a day. According to these authors, grazing ruminants under fluctuating feed supplies produce a constant amount of fecal output per unit live weight [22]. Livestock numbers were collected using the questionnaire.

Additionally, the amount of manure currently available (i.e., piled) in the farm was estimated using direct manure measurements and calculations as suggested in Brodie [23].

2.4. Determination of Manure Quality and Its Economic Value

Manure samples from the nine farms were taken from the surface heap (30 cm depth) on eight random spots representing different ages and moisture conditions. The collected samples were thoroughly mixed and a composite sample of 1 kg was taken using a hand-in bag method and transported to the Hawassa University soil laboratory. There, it was air-dried and ground to pass through a 2 mm sieve. The manure was analyzed for organic matter content, pH, phosphorus (P), total nitrogen (TN) and potassium (K) according to the recommended methods [24,25]. Subsequently, the amount of nutrients available for crop production and their economic value was estimated. In an economic valuation of manure, the major emphasis was on the replacement value of N, P and K, as these nutrients are the limiting factors in crop production [26]. In the present study, the replacement cost of inorganic fertilizer (i.e., on an inorganic fertilizer-equivalent rate based on current agronomic recommendation and market value) was used to quantify the economic value of manure.

2.5. The Response of Maize Grain and Stover Yields to Manure

An on-farm experiment was conducted during the 2015/16 cropping season in a randomized complete block design with three replications. Two model agropastoralists were chosen purposefully to host all the treatments of the trial. The treatments were: (1) control receiving no manure and fertilizer (to show agropastorals' usual practice); (2) recommended practices (100 kg diammonium phosphate (DAP) ha^{-1} and 100 kg ha^{-1} urea at 30 days after planting); (3) manure micro-dosing (point application of 70 g (corresponds to 3.71 tons per ha) of manure per planting pocket); (4) five tons (equivalent to 35.45 kg of N ha^{-1}) of manure ha^{-1}; (5) five tons of manure plus intercropping; (6) manure micro-dosing plus fertilizer micro-dosing (i.e., point application of 70 g of manure plus 0.5 g of fertilizer per pocket); (7) manure micro-dosing plus intercropping. In each farm, a plot size of 43 $\times$ 26 m that was divided into three blocks was established. The plot size for each treatment was 40 m^2 (8 $\times$ 5 m). In plots receiving broadcasted manure, 20 kg plot^{-1}, corresponding to five tons per ha was spread over the plots and superficially incorporated into the soil with a long-handled hoe. All the cultural practices were carried out by the agropastoralists. Yield measurements were taken from each plot of both farms.

2.6. Statistical Analysis

Analysis of variance (ANOVA) was performed using SPSS (version 24) to determinate differences in land allocation for different enterprises, manure production potential and livestock to useable farmland ratio between the resource groups. A least significant difference at the probability level of 0.05 was used to delineate significant differences among the resource group means. Standard errors of means of the resource groups are presented. For the variables that did not show statistical differences, or in cases when it was difficult to compare, the results are presented in an illustrative form. Grain and stover yield data were also subjected to ANOVA and means were tested using least significant difference (LSD) at $p < 0.05$. The report was made based on pooled data.

3. Results and Discussion

3.1. Farm Characteristics, Manure Utilization and Opportunity for Pasture Development

The Borana agropastoralists are characterized by large livestock ownership and mixed land use (Tables 1a and 1b). On one hand, livestock farming was well established in the study area. On the other hand, crop cultivation has become an important component of the farming system in recent years. Generally, crop farming was expanding in many parts of the study area, not merely for subsistence but to diversify household income. The total farmland held by the households, excluding home compounds, was 2.15 ha (on average), and all the studied households were engaged in crop production on their private crop fields. The observed mixed farming system reflects the integration of crop–livestock production system primarily cattle, sheep and goats with annual and perennial crops (i.e., fruit trees and *Moringa stenopetala)* (see Table 1a), and suggesting the growing importance of crop cultivation in the study area.

Table 1a. Farm characteristics in Borana, southern Ethiopia.

		Mean	Resources groups (n = 30)		
			Rich (n = 9)	Medium (n = 7)	Poor (n = 14)
Farm skill training (% HH head)	None		26.7	23.3	46.7
	Short-term		3. 3	0	0
Education of HH head (%)	None		16.7	23.3	26.7
	Adult education		10.0	0	6.7
	Primary school		3.3	0	13.3
Farm assets					
Farm land (ha)		2.15 (0.24)	3.46 (0.33)	2.7 (0.37)	1.19 (0.19)
Livestock (TLU)[a]		24.09 (2.5)	41.60 (2.5)	24.90 (2.1)	12.44 (0.7)
Land allocation in %					
Cropped area (three major crops) [b, c]			64.41	51.69	57.14
Grass patch area			7.45	25.85	30.25
Cash cropped land[d]			10.47	13.56	10.10

[a] TLU: tropical livestock units, equivalent to an animal of 250 kg weight; [b] land allocated for mixed use not seen in the table, [c] maize, "teff" and wheat; [d] primarily sugar cane plot; HH: household; values in parenthesis are standard errors.

As in many parts of the country, maize, teff and wheat were allocated the largest share of the cultivated area of most farms. Almost all the crop fields were situated in valley bottom sites and along floodplains to make use of the seasonal flooding. Foot-slopes were also cultivated. The average livestock holding (TLU) per household in the study area was 24.09 TLU, higher than that reported by Yonas et al. [27] and Abate et al. [28] in agropastoral areas of southwest Ethiopia (22.31) and southeast Ethiopia (10.3), respectively. This large livestock holding could be an opportunity for increased manure supply.

Table 1b. Land allocation (in ha) for different enterprises.

Resource Group	Total Farmland	Cropped Area [a]	Cash Cropped Area	Grazing Pasture Plot	Mixed Plot
Rich	3.46	2.17	0.36	0.26	0.61
Medium	2.37	1.22	0.32	0.61	0.21
Poor	1.19	0.68	0.11	0.36	0.04
Mean	2.15	1.26	0.23	0.39	0.25
se±	0.24*	0.18*	0.05*n.s.*	0.11*n.s.*	0.10*
p-value	0.000	0.000	0.081	0.48	0.000

[a] Cropped area comprises cereals and common bean plots; *n.s.* and * indicate not significant and significant at $p \leq 0.05$, respectively.

Regardless of their wealth category, all the studied households used neither fertilizer nor manure. Absence of fertilizer use was related to the unfamiliarity and/or inaccessibility of fertilizer. In Borana, there is no tradition of using fertilizers in general [29]. In the study area, respondents stated that manure was stockpiled for periods of seven years or longer. The manures heaps were not considered by the agropastoralists as valuable source of nutrients owing to traditional beliefs, limited knowledge and lack of extension services (see details below in Section 3.3). This is different from the situation in other parts of Ethiopia where manure is a highly appreciated and valuable resource in mixed farming systems [17,30]. Similarly, settled Fulani pastoralists in West Africa also depend on corralling cattle overnight on farmland to enrich the soil [13,18].

Households, particularly the resource-poor and medium group, were allocated more than a quarter of their farmland to fodder production (Table 1a) for grazing and fodder sale. During the study period (i.e., 2015/16), fresh cut grass forage was sold often at a price of 25 ETB (Ethiopian Birr) (US$1.22) per load. The habit of fodder sale by the producers might offer an opportunity to demonstrate the use of manure in the study area. If agropastoralists are shown the benefits of using manure, some may start to apply it to enhance their forage production, and thereby increase their income. Studies suggest that increased profitability is an incentive for adoption of an innovation or technology [18]. Furthermore, forage productivity, particularly the herbaceous layer, is low in Borana, see for example [31]. In this regard, the huge livestock population and substantial amount of manure available (see Section 3.5.) would be a good opportunity for promoting pasture development using manure in the study area. The use of dung and urine on pasture plots to improve grass growth and productivity is a widely adopted practice in other parts of southern Ethiopia [17].

3.2. Agropastorals' Perception of Soil Fertility Status

In this study, soil fertility status of crop fields was explored through FGDs, and field visits. Participants involved in FGDs developed and prioritized indicators to evaluate soil fertility status of crop fields. Consequently, soil type (primarily its color, i.e., red versus black to brown colored soils) and the occurrence of weeds were used as the main indicators to distinguish between fertile, low fertility and degraded crop fields. According to the agropastoralists' judgment, the red colored soils were considered less fertile while black to brown soils were perceived as very fertile or productive. The water-holding capacity of the soil was also assessed based on its color. According to the perception of FGD participants, black-brown colored soils were the most appreciated soils in terms of water-holding status compared to red soils. This is in agreement with Gray and Morant [32] and Birmingham [33], who found that smallholders are knowledgeable with regard to defining major soil types and the fertility status of their farms by taking into account the color, texture and moisture retention of soil as a basis for their classification.

Of the observed farms, over half (53%) of the croplands were identified as less fertile, while 37% of the studied farms were perceived as fertile (Figure 1). The position of the cropping fields along the landscape might explain the observed fertility status of the studied farms. The majority of the crop fields in the study area were located in the bottom valley sites and flood plains. Cropping fields, which were perceived as degraded, were situated in uplands. It has been reported that soils located in valley bottom sites in semi-arid areas of southern Ethiopia are often poorly drained and are expected to have better fertility and water-holding capacity than hilltop soils [1]. This is in line with the current perceptions of agropastorals. Coppock [1] also notes that although water is assumed to be the major limiting factor for plant growth, in semi-arid areas, nutrient limitations could be an important constraint in run-on areas in drylands where water availability is less of a constraint. To confirm the perceived fertility status, scientific observations are required.

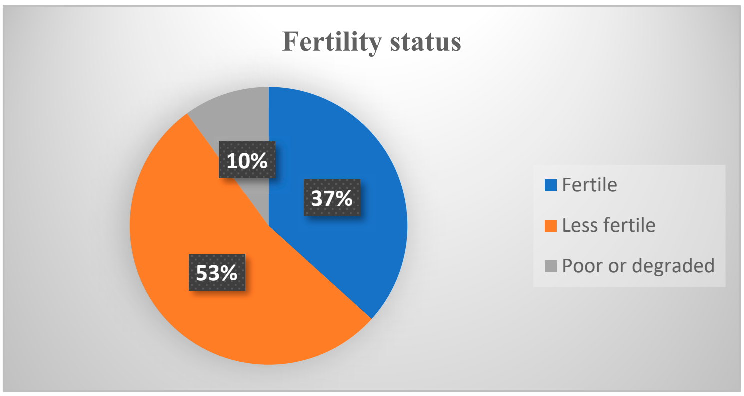

Figure 1. Perceived fertility status of soil.

3.3. Why the Borana Agropastoralists Do Not Use Manure: The Influence of Traditional Beliefs

As stated in Section 3.1, there is no tradition of using manure in Borana. In many parts of Ethiopia, for example, [34] and other SSA countries [12,35], it is widely acknowledged that quantities of manure available to the farmers are limited because of low numbers of livestock per household, thus constraining crop production. Even in areas that have large livestock populations, and thus, large volumes of manure, labor requirements hamper manure utilization [17]. This is different from the situation that prevails in the study area, where manure does not have a value as a fertilizer. As compared to other agropastoralists of SSA, the Borana may be unique, to say the least, in possessing a large livestock population and an enormous amount of manure (see Section 3.5.) without benefitting from this resource.

In order to understand the barriers to the use of manure, key informant interviews were carried out with five highly regarded elders independently. Our discussion with the elders revealed that the entire olla have to move to a new place every seven to ten years, as a result of the size of the manure heap. They move because dangerous animals such as 'python snake' are attracted to the heap. People associate this with misfortune or with bad things expected to happen in the community. Therefore, they move to another site. The occurrence of dangerous animals was seen as an indicator to move to another site, or as an expression of the necessary action (i.e., relocate the olla) to please the will of God. Dangerous animals are also seen as evil carriers that God uses to punish those who violate God's rules. According to the village elders, failure or delay to relocate one's olla despite having seen the indicators is seen as dishonoring God's will. The consequences are spiritual retribution, such as loss of livestock, illness, physiological disorders or sudden death. There were stories of such outcomes, according to the village elders.

Above all, the communities in the study area believe that their animals die if their dung (from the heap) is used for any purpose other than plastering their house floor. During the fieldwork, informants often stated that there was a belief among the communities that if they used their animals' dung, they would offend the creator God and this could bring suffering or misfortune to the offender's animals, family and perhaps even to the whole olla and the village. In line with this, we observed that some of the households were not even willing to let their manure heap be measured and sampled, saying that God may be dissatisfied and punish them. Mather and Hart [36] in Kenya have made similar observation. These authors reported that there was believe among the Kikuyu tribes that cattle will become possessed of an evil spirit (thahu) and die if their dung is placed in the soil or removed.

In the present study, the observed unwillingness among some studied agropastoralists, together with the information obtained from elders can suggest that the traditional beliefs (and concepts regarding manure) appear to negatively influence the community's attitude towards manure. This can explain the observed non-use of manure in the area. Because all the elders gave an unambiguous answer regarding the use of manure, it is possible to assume that this observation is valid for the whole study area. Nevertheless, this information cannot be extrapolated to the whole agropastoral areas of southern Ethiopia, because such traditional beliefs are area-specific constructs influenced by local social, cultural, economic and biophysical circumstances [37,38]. Therefore, further investigations are necessary to substantiate the current observation.

In areas where application of scientific knowledge and educational services are lacking, people use their indigenous systems of beliefs to make choices, understand and interpret their biophysical environment, and make decisions [39] as seen in many instances in Africa [40,41]. Evidence suggests that although such beliefs and practices may have positive consequences [42], they can also generate unfavorable attitudes and anxieties towards innovation, restrict adoption of innovations, and impede economic progress [37,39]. For instance, from the analysis of panel data on 26 African countries, Nkamleu [43] reported that countries dominated by indigenous believers have shown lower rates of agricultural growth, particularly in terms of technological progress between 1970 and 2000, thus implying the possible negative effects of traditional beliefs.

Lack of knowledge or unfamiliarity with the use of manure was the second reason given for the non-use of manure in the study area. As it is a drought-stricken area, there are many non-governmental organizations (NGOs) working in the area. However, none of the organizations engage in manure research, technical support or promotion. This is most likely because their entire focus is on livestock production and/or rangeland management, in addition to ignorance of the potential use of manure. The observed lack of awareness of manure's potential may also be related to the households' low level of education. Two-thirds of the studied household heads had not attended school at all or had a very low level of formal education. Just under 17% of those surveyed household heads had basic (adult) education. Almost all of the households had no farm skill training at all, and had not attended pastoral-training centers (see Table 1a). This is contrary to the farmers in the highland areas of the country, who receive farm skill training once every year. Similarly, Megersa et al. [4] report a lack of formal education among the Borana agropastoralists.

3.4. Livestock Housing and Manure Management

No statistical analyses were performed as all the respondents had similar responses (no variation observed) to the questions asked about manure management and housing. Therefore, the results are presented in a descriptive form using figures for illustration. Animals in the study area were freely grazing during daytime (10–11 hours) and were corralled at night in a house or kraals (locally called "monaa"). Every Borana household had livestock kraals and manure heaping sites at the edge of the household's compound. All the studied households had separate kraals for large cattle (Figure 2), mature sheep and goats (Figure 3c), calves (Figure 3d) and for lambs and goat kids (roofed and constructed 30–50 cm high above the ground) (Figure 3a,b, respectively).

Figure 2. Large cattle kraal (locally called monna) in Borana, southern Ethiopia. Photograph by the first author.

The large cattle kraals are slightly sloping with a salt trough located in or outside the kraal. The Borana traditionally supplement livestock with crude salt mined from local volcanic craters.

The composition of this salt was found to be 41% NaCl with minor quantities of macro and trace minerals [1]. We visually observed that manure was swept from the kraal and heaped in an open-air site (Figure 4) located outside the kraal. The studied households were observed to use their bare hands to remove manure accumulated in the kraal; cattle hide was used to throw manure onto the heap. None of the studied households had a defined time or number of intervals per week to collect and remove manure from their kraal. Rather, the amount of manure accumulating in the kraal determined when the manure was to be swept from the kraal – usually done daily or up to every fifth day. While manure sweeping is women's duty, men are responsible for building and repairing kraals.

Figure 3. Kraal for goat kids (**a**) and lambs (**b**), matured sheep and goats (**c**) and calves (**d**) in Borana, southern Ethiopia. Photograph by the first author.

As with the kraals, the manure from cattle, sheep, goats and camels manures was heaped in separate sites. The informants explained that if heaped in the same sites, seedlings of weed species–especially acacia species such as *Acacia brevispica* Harms, A. *drepanolobium* and A. *seyal* Del–could establish themselves from within the intact dung pellets of sheep and goats. Separate heaping sites were used to avoid this perceived problem. Furthermore, almost all (29 of 30) respondents had only one cattle manure heap; the remaining respondent had two cattle manure heaps. According to the informants, establishing new heaping sites in the current olla is not part of their tradition. If there is a lot of manure, the practice is not to establish a new site, but to abandon the heap and move to a new place, leaving the old heap undisturbed. This is because prolonged practice of storing manure at the same site leads to large accumulations of dung. Informants further mentioned that the average age of a manure heap when it is abandoned, from their long experience, is around seven to ten years. When the manure heap reaches this age, dangerous animals are attracted to the heap.

On average, the manure heap was situated about 25 minutes' walk from the cropping fields and four minutes' walking distance from the owner's house, respectively. This could present an opportunity to encourage the use of manure for crop production. Since the heap is located near the cropping fields, transporting manure to the fields would then require less time and energy [44].

From our field observations, with the current management (storage and accumulation, Figure 4), nutrient losses and emissions of ammonia and of nitrous oxide from the manure are expected [45]. Research has shown that losses of nutrients, mainly due to leaching and volatilization, from cattle dung were much higher where dung was piled and remained uncovered [13,14]. Even though its effect was not examined in the current study, land application of manure, though varied with environmental conditions, application rates and spreading techniques, is associated with emissions that are responsible for a range of environmental damages [46,47]. Other possible problems related to utilization of manure on cropland include high costs associated with hauling and spreading the bulky materials [48].

Figure 4. Representative pictures showing cattle manure heaps (dunghills) in Borana, southern Ethiopia. Photograph by the first author.

3.5. Manure and Nutrient Production in Borana

Considering the large population of cattle and separate accumulation of manure in the study area, in the current study, we only measured the cattle manure. Tables 2 and 3 show cattle population per cultivated area, theoretically estimated manure, farm-available manure and corresponding nutrient supply.

3.5.1. Theoretically Estimated Quantities of Manure

The average total (theoretically estimated) manure production per household of the studied households (30) was estimated to be 16.85 tons per year (Table 2). The quantity of manure produced varies considerably among the resource groups due to differences in herd size. Smaller manure production (8.9 tons) for the resource-poor households can be explained with small cattle herd size, see for example [49]. The cattle population to farmland ratio shows no significant variation among the resource groups.

Table 2. Average TLU per cultivated land and theoretically estimated amount of manure per household resource group in Borana.

Resource Group	Farmland (ha)[a]	Cattle in TLU	Estimated Manure (tons)	TLU Per Farmland
Rich	3.46	32.51	28.28	10.45
Medium	2.36	20.90	18.20	9.87
Poor	1.19	10.15	8.90	9.70
Mean	2.15	19.37	16.85	9.98
se±		1.90*	1.65*	0.97*n.s.*

[a] Farmland = land used for arable crops + cash crops + grazing pasture + mixed crops. *n.s.* and * indicate not significant, significant at $p \leq 0.05$, respectively.

3.5.2. Manure Available on Farm: A Hidden Resource

Besides the as-excreted estimate of manure that could be produced in the farm, we measured manure currently available in the farm from nine randomly selected farms. The average amount accumulated over the years in the heap was 74.1 tons. In Ethiopia, based on current agronomic advice, 100 kg of urea (expressed as 46-0-0) and 100 kg of DAP (18-46-0) expressed as 18% N, 46% P_2O_5 and

0% K_2O by weight is applied to maize per hectare. This corresponds to 64 kg N/ha. In this study, it was estimated that, on average, one ton of manure contains 9.03 kg of N (Table 3). Thus, 7.09 tons manure/ha corresponds to 64 kg/ha of N in the study area. With this application rate, the average amount of manure currently available in the farms would be sufficient for manuring more than 10ha of maize crop land which is five times greater than the land currently under cropping (Table 3). Assuming the studied households' response on the non-use of manure is representative of the whole study area, an enormous amount of manure is not made use of. This estimation did not consider potential losses due to management and soil application of manure which cannot be avoided [45,50].

Table 3. Manure production (ton) and nutrient contents (kg/ton) and total outputs in Borana, southern Ethiopia (based on nine farms).

	Cattle in TLU	CL (2015/16)	AM (ton)	MNC (kg/ton)			TO in kg per Farm		
				TN	P_2O_5	K_2O	TN	P_2O_5	K_2O
Mean	**26.83**	**1.70**	74.11	9.03	0.12	3.98	667.87	9.14	320.53
Stdev	7.07	1.20	61.20	1.49	0.01	1.42	565.62	8.38	365.47

CL: Cropped land; AM: Amount of manure; MNC: Manure nutrient concentration; TO: total nutrient outputs.

3.5.3. Nutrients Potentially Available for Crop Production

The plant nutrients nitrogen (N), phosphate (P_2O_5), and potash (K_2O) are the most yield determining nutrient inputs in most farming systems [51]. Manure contains a substantial amount of these nutrients and others such as magnesium and sulphur. It was found that one ton of manure contains 9.03 kg N, 0.12 kg P_2O_5 and 3.98 kg K_2O (Table 3). As compared to the other two, phosphorus availability is very low which may be attributed to low P availability in the soil in the study area. Studies have shown that P content of the soil in the Borana rangeland was very low [5], which in turn affects plants' P level. As outlined in Table 3 above, the measured amount of mean total manure was 74.11 tons. From the analysis, the mean total available N was found to be 667 kg. The P_2O_5 output was 9.14 kg and K_2O output was 320 kg, found on average in each farm, though considerable numerical differences among the studied farms were found (see Supplementary Material Table S1).

3.6. The Economic Value of Manure as Fertilizer (in Monetary Terms)

As a plant nutrient source, manure can provide an economical source of N, P and K for plant growth and reduce the cost for fertilizer (Newton et al., 2003). However, in the study area, manure does not have known economic value. Our analysis revealed that 667.87 kg of N, 9.14 kg of P_2O_5 and 320.53 kg of K_2O are, on average, available in each farm. In this study, the value of N was only used as indicator to estimate the fertilizer value of manure.

During the survey year of 2016, the price of mineral N fertilizer was ETB 24.63 per kg. The market price attached to the nutrients in this study was the price that the agropastoralists would have to pay if the produce were to be purchased. This is because manure in the study area does not have market value. Accordingly, if the agropastoralists were supposed to use N fertilizer, the above-measured nutrient is equivalent to an economic value of ETB 16452 (US$802), which could be attributable to N fertilizer. The economic value of manure N is shown in Table 4. Although manure utilization is not in practice, this analysis indicates that there is a considerable scope for using manure to increase yield and food security in the Borana agropastoral areas. However, the exact scope for improvement requires further quantification and detailed studies of the nutrient flow across the landscape.

Table 4. The value (ETB) of nitrogen in manure produced on farms.

Nutrient	Nutrient Price Per kg	Total Nutrients Output	Total Monetary Value (ETB)
N	24.63	667.87	16452.84

**ETB (Ethiopian Birr) 20.52 (March-2016) = US$1.* The value of manure was estimated based on fertilizer-equivalent rate (N in urea and DAP and P in DAP) and value.

3.7. Implications for Cropland Productivity and Nutrient Management

The agropastorals in the study area have sufficient manure N to apply to their croplands. In relation to the requirement, about 613% of the N and 16.7% of the P fertilizer needs can theoretically be met with manure if all the available manure (collected from the kraal) was used to fertilize maize croplands. Hence, manure could make a significant contribution to plant nutrient supply for the study area. From the analysis, the quantity of N to potentially be generated from manure was in excess of requirements (more than five times the current requirements), indicating considerable scope for the agropastorals to increase yield substantially by using manure, even if they lack access to fertilizers. The excess to N supply of what is currently needed suggests that an important role which government or another development organization could play, would be to facilitate and promote use of manure in the study area. However, crop P needs would not be met through manure applications alone.

3.8. Yield Responses for Manuring in Borana

Maize responded positively to manure application. Responses in grain and stover yield to manure and fertilizer application are shown in Table 5. All treatments recorded significantly higher grain and stover yield of maize than did the control treatment that received no nutrient inputs.

The highest grain and stover yields were achieved where micro-doses of manure were combined with micro-fertilizer, followed by the recommended dose of fertilizers. Application of 70 g (corresponding to 3.71 tons per ha) of manure, combined with a small quantity (0.5 g per pocket) of fertilizer, improved maize grain yield by 77% compared to non-use of inputs. Additionally, manure applied alone yielded 51% of grain compared to the control. This is in close agreement with the findings of Ademba [52] in South Western Kenya where animal manure applications resulted in a substantial increase in maize yield over the control. Maize stover yield followed similar trends to the grain yield (Table 5). Despite variation between treatments, the observed significant yield improvements compared to the usual non-use of manure shows considerable scope for increasing yields of these marginal lands by using manure. Thus, there is a potential to promote manure use in agropastoral areas of the Borana if the traditional beliefs withholding its use are eradicated. However, the observed yields at farm level are far below the potential (i.e., suggested to be 2000–3000 kg ha-1) [53], which require further investigation. An analysis of the cost-benefit ratio is also required to show the returns of manure for the agropastoralists.

Table 5. Yield responses of maize for manuring in Borana, southern Ethiopia.

Treatment	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})
Control	701.00±46	2013.82±95
Recommended practice (mineral fertilizer)	1231.12±46bc	3181.58±95b
Manure micro-dose (3.71ton ha^{-1})	1015.00±46a	2684.87±95a
5 ton of manure†	1059.00±46ab	2546.49±95a
5 ton of manure + legume intercrop	929.70±46a	2572.15±95a
Manure micro-dose + fertilizer micro-dose	1240.60±46c	3386.62±95b
Manure micro-dose + legume intercrop	1015.60±46a	2564.69±95a
LSD	186.2	386.91
p-value	0.00	0.00

Standard errors are given by signs '±'; †: equivalent to 35.45 kg of N ha $^{-1}$. Means within a column with different or no letters are significantly different (p<0.05).

4. Possible Areas of Interventions

Despite the enormous potential manure has for smallholders, it remains un-utilized in the study area. The observed large amount of manure with substantial fertilizer value, high manure production potential, and unavailability of fertilizer could be seen as an opportunity for intensification using manure. Rogers [54] notes that personal characteristics such as an individual's values and beliefs, among others, can influence adoption decisions. Our results show that, indeed, traditional beliefs have negatively affected decisions to use manure by the agropastorals in Borana. These beliefs are enhanced by lack of awareness and knowledge limitations about the values and uses of manure. Addressing these factors could promote use of manure in the area. The following section gives an overview of the possible areas of interventions.

4.1. Institutional Support to Overcome the Barriers and Promote Manure Use

The barriers outlined above are all related to limited access to education, extension services and technical information regarding manure use and its management. Therefore, eradicating the barriers requires concerted efforts through cooperation and understanding of community leaders, research institutions, development agencies and decision-makers. Carefully planned information campaigns and education, which encourage adoption of manure use and counteract those factors that act as barriers, may change the current attitude towards manure. Community education (via local media), because it helps to promote a rational worldview, might be vital in increasing public awareness of the negative influences of the existing societal beliefs and associated practices. It may also enhance the level of awareness of the farming household about the virtues of manure use. In this regard, the growing use of mobile phones in the area might offer an opportunity for reaching agropastorals to access and spread (and share) information. Increased knowledge on the merits of manure can be achieved through radio programs addressing these issues. Working to increase the awareness about the merits of manure use would produce more change than would efforts to diminish objections to manure application. Farm skill training on manure use and management by the extension service can transform the attitude of the households' so that they can become adopters of the innovation. Extension services can further address the barriers to manure use. Studies have shown that producers use of manure was positively and significantly associated with the availability of training and of extension services [17,55], which must be emphasized in the study area.

4.2. Manure for Crop and Pasture Development

Agropastorals in the study area suffer from serious food and feed shortage problems [4,56]. This study has shown a large supply of manure that is left unused. This manure can potentially be used to promote maize production, which increases grain supply for human consumption and fodder (stover) for animals. Furthermore, there is a possibility of forage development by using manure. In this regard, agropastoralists in the study area are currently setting aside land for fodder production and this represents a niche for manure use. Manuring grasslands is widely practiced in some parts of southern Ethiopia [57].

4.3. Option to Enhance Use of Manure in Agropastoral Farming Systems in Ethiopia

Contemporary proposals for enhancing agricultural productivity on the African continent strongly support the introduction and expansion of sustainable agricultural practices. In this regard, currently, crop (both forage and food) productivity can be maximized within agropastoral systems in Africa through two basic alternative scenarios. The first involves the more effective utilization of resources internal to the agro-ecosystem, e.g., manuring, mulching and intercropping with leguminous plants), while the second is based on the increased use of external inputs (e.g., chemical fertilizers). This study shows, though nearly two-thirds (63%) of the croplands were as less fertile and degraded, the agropastorals in the study area used neither fertilizer nor manure. Application of external input-based alternatives might be difficult in the study area due to the cost of the input and accessibility. Instead, intensive utilization of manure is relatively cheaper than purchasing chemical fertilizer, more appropriate to the Ethiopian agropastoral systems and environmentally friendly. The large amount of manure currently available in the study area and the observed yield response represent an opportunity for intensification of crop production. In this regard, with the aim of increasing crop and pasture production, starting with a few agropastoralists, manure demonstration projects should be established at the village level to demonstrate its value. This could be undertaken as a collaboration between the local pastoral development office, research center, NGOs and with active involvement of the communities (using model farms or test agropastoralists). Such a community-based approach, which focuses on raising knowledge and participatory application/adoption of technologies at village level, has proved successful in the piloting of adaptation strategies in Kenya and Nepal [58,59].

5. Conclusions

This study has explored status of manure use, manure nutrient supply potential, and its implication for agricultural production in the semi-arid agropastoral systems of southern Ethiopia. Based on the findings of this study, it appears that crop yield from the nutrient-poor soils of the Borana can be substantially enhanced by using manure. However, despite this fact, manure is left unused in Borana, while the agropastoralists continue to suffer from the widening gap between food and feed production and population growth. The study shows that the potential of manure to improve crop yield in the study area is limited by traditional beliefs prevailing in the community. The traditional beliefs linking manure use to misfortune and loss of livestock have a negative influence on manure use and management. These beliefs are understood to be key causes for not realizing the potential of manure to support crop production in the study area. We believe that these beliefs have prevailed for years in the community because of factors such as lack of education, lack of manure research and the lack of extension service and technical support. Thus, there is a need for farm skill trainings and education programs or campaigns, combined with village-level manure demonstration projects to show the value of manure. These should be accompanied by community-level dialogue with the agropastoralists regarding the cultural issues and traditional beliefs related to manure utilization and management.

Supplementary Materials: The following are available online at http://www.mdpi.com/2077-0472/9/3/45/s1, Table S1: Manure production (ton) and total nutrient output (kg).

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