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Three Interwoven Dimensions of Natural Resource Use: Quantity, Quality and Access in the Great Limpopo Transfrontier Conservation Area

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Abstract Quality and quantity of natural resources are often studied in isolation from access. We question the usefulness of this separation for resolving conflicts over natural resources and present an approach that facilitates a deeper understanding of natural resource use through a joint analysis of quantity of, quality of and access to resources. The approach was developed as part of an in-depth case study of resettlement in southern Mozambique in which newly resettled residents struggled to reestablish their livelihoods. We estimated the quality and quantity of, and investigated rules and norms of access to four key natural resources: water, agricultural fields, grazing, and forest resources in both pre- and post-resettlement. We then contrast this with the actual access that resettled residents gained to these resources in practice, what we call 'accessing.' Our analysis suggests that locally-specific, dynamic relationships among quality, quantity and access are critically important for understanding human-environment interactions and natural resource-based livelihoods.

Keywords Natural resources · Interdisciplinary · Access · Resettlement · Livelihoods · Mozambique

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Introduction

Residents of rural areas across the world depend on natural resources for their livelihoods. Conflicts over natural resources and competing claims on the same resources are increasing in number and intensity (Escobar 2006; Giller *et al*. 2008; Nie 2003). How to deal with these competing claims in an equitable way requires greater insight. Competing claims on natural resources are characterized by multiple uses and users of resources, and divergent cultural, economic and environmental valuation of resources across scales (Giller *et al*. 2008). This complexity poses challenges for designing or assessing interventions aimed at equitable and sustainable use of natural resources, especially when it comes to understanding how to protect the livelihoods of the people most directly dependent on natural resources on a day-to-day basis.

The challenges begin when the researcher, consultant or practitioner tries to understand resource use. First, it is necessary to know how much (quantity) of a given resource is available, but the quality of that resource for the desired use is also of utmost importance. For example, a large area of land may be available for farming, but the areas in which the soil is of good quality have more value and can be more intensively used than the areas of low soil fertility, on a slope, or full of stones.

Focusing exclusively on quantity and quality, however, reveals only part of the relationship between people and natural resources (Leach *et al*. 1999; Li 2001). If the resource cannot be readily accessed, the use of that resource in practice is likely to differ from a situation in which the resource is accessible freely to everyone. Access, who can benefit from how much of which resources (Ribot and Peluso 2003), shapes resource use within the limits of the resources that are available. Dynamics of access, as described in more depth below, are riddled with questions of power; the rules and norms of access change in response to both social and ecological processes (Agrawal and

Gibson 1999; Berry 1989b). Studies have shown that the quality and quantity of natural resources also change in response to both social and ecological processes (Leach *et al*. 1999: 232), primarily mediated by access. The quantity and quality of and access to a resource are three interwoven factors that ultimately determine natural resource use.

Social science studies that focus on access to natural resources rarely consider the quantity and quality of those resources, leaving a considerable knowledge gap concerning resource availability. Similarly, many studies from a natural science perspective focus on assessing the quantity and quality of the resources at hand, but fail to consider peoples' access those resources. Even interdisciplinary studies rarely investigate all three factors thoroughly. The Millennium Assessment, for example, a multi-scaled study that took account of human well-being and human use of resources, aimed to "understand the consequences of ecosystem change for human well-being." Yet it still focused primarily on the quantity and quality of natural resources (Scholes and Biggs 2004). In fact, the only millennium development goal that deals with the management of natural resources (MDG7) uses area of land as the basis of the two indicators defined for resource conservation, and overlooks quality (Roe 2003) as well as access. Many articles state the need for both social and biophysical data to inform improved policies and promote sustainable natural resource management (Blaikie 1989; Ostrom 2009). While calls for interdisciplinary research to better understand human-environment relationships have intensified, the disciplinary divide remains significant between social and natural scientists (Lele and Kurien 2011; Walker 2005; Walters and Vayda 2009).

Based on an in-depth, interdisciplinary case study of resettlement, this paper aims to contribute to a wider understanding of how the relationships among quantity, quality and access to resources influence actual resource use and how resource use in practice, considering these relationships, can be better understood. The context of resettlement is ideal for studying these relationships because resettled residents are forced to establish new patterns of access in a short period of time. While patterns in post-resettlement may not reflect those of a well-established village, this paper focuses primarily on understanding the relationships among the interwoven dimensions that influence resource use, not the patterns themselves.

In southern Mozambique the establishment of the Limpopo National Park (LNP) in 2001 laid claims to land and water in an area in which approximately 27,000 people reside. Conservation managers, supported by international donors, made the decision to resettle some of the residents to locations outside the park's borders. Resettlement planning was driven by questions about how much (quantity) of which resources (quality) people would be entitled to as compensation for resettlement. The residents to be resettled, however, continually pointed to another type of question: will we be well received in the new location? This question in practice meant, among other things, will we be able to access the resources we need? Before resettlement took place, Witter (2010), through research in another village in the LNP, found that fear of losing access to and especially control over the access to resources was one of the main reasons that residents were resistant to resettlement. Control of access to resources is associated with power and leadership which, in the study site, has traditionally been transferred through lineage (Witter 2010). It is not surprising then that once the first village was resettled, we found that there were differences among the formal access to resources presumed by the government as part of compensation for resettlement, the informal rules regarding access to resources, and access in practice. For example, resettled residents were expected to access resources on the same terms as the existing residents of the area. In practice this was not realistic because the mechanisms to gain and maintain access to resources were not in place for the resettled residents, as described further in this paper. Because of consistent confounding of the rules and norms of access, and the constantly negotiated day-to-day interpretation of those rules we will use the word *accessing* to refer to access in practice.

In order to assess why resettled residents struggled to survive in their new environments, this study analyzes how the relationships between quantity, quality and access influenced resource use in post-resettlement. For each of the four most important resources, we describe the quantity and quality in the post-resettlement location and outline the rules and norms of access. We then describe the challenges faced by resettled residents in accessing resources in their new location and analyze the relationships among these dimensions. This paper turns now to define and describe access as a theoretical concept and in the context of resettlement before turning to the case study.

What is Access?

The definition of access we use is "the ability to benefit from things" (Ribot and Peluso 2003:153). Ribot and Peluso (2003) identify key mechanisms that may influence or facilitate access (Table 1). These mechanisms can be rights-based, defined by law, custom or convention, whereby the state, or customary governing body will enforce a legal claim or oppose an illegal action (Ribot and Peluso 2003:162). Structural and relational mechanisms function in parallel to rights-based mechanisms. These are the political, economic and cultural factors that limit or enable a person's ability to benefit from a resource. These mechanisms include technology, capital, markets, labor, knowledge, authorities, identities and social relations. While Ribot and Peluso (2003:162) recognize rights-based mechanisms to include custom or convention, we added customary institutions as a separate rights-based mechanism to differentiate between informal and law-based rights (Table 1). All of these mechanisms are interrelated and can function sequentially, simultaneously or in opposition to one another (Ribot and Peluso 2003).

Table 1 Mechanisms of access, adapted from Ribot and Peluso, 2003

Type	Mechanism	Definition	Examples
Rights-based	Legal	Rights attributed by law	Rights to property through a title or deed
	Institutions	Rights secured through informal rules	Customary recognition of inheritance of land
	Illegal	Benefiting from things not sanctioned by law or society	Theft, squatting, violence
Structural and relational	Technology	Use of a technology or a tool makes it possible to extract resources otherwise not possible, physically reach a resource, facilitates faster extraction, etc.	Plow, fence, tubes, pumps, electricity, roads, cars, weapons
	Capital	Capital can be used to purchase technology, tools, labor, and rights to resources, to leverage more capital (loans), to stake claims	Purchase of technology for extraction, production, conversion, credit, plant trees to stake claims on land, pay for travel to bargain for access with authorities
	Markets	Markets allow the resource owner to commercially benefit from it	Existence of, distance to market, price of commodity, preferential treatment
	Labor	Those who have labor available to them, or who control labor opportunities can benefit from a resource that otherwise would remain unexploited, allocate labor opportunities as favors, and bargain down wages	Laborers in an agricultural or extraction setting allow for more production. As a laborer, ability to work and to maintain access to employment with others also brings benefit from resources otherwise not available
	Knowledge	Knowledge and information can bring direct benefits from resources. Ideological controls and discursive practices also shape who can benefit from which resources	Information about prices, education, expertise, cultural taboos, ethics. Discourses, for example about the value of getting a job over cultivating the land
	Authority	Individuals or institutions given authority influence who benefits from which resources as nodes of direct or indirect control	Laws, permits, lobbying, favors, allocation of labor opportunities, direct allocation of resource use rights
	Identity	Identity or membership in a group can determine who can benefit from which resources	Age, gender, ethnicity, status, profession, place of birth, historical claims
	Social Relations	Social relations are key to all mechanisms of access	Friendship, trust, kinship, reciprocity, patronage, dependence

Some people control access to resources, such as those who are in positions of authority, while others maintain access to resources through those who control them using the mechanisms described (Ribot and Peluso 2003).

Informal rules and norms about access shape who can access which resources through which mechanism (Agrawal and Gibson 1999; Berry 1989a). Mechanisms of access may differ according to the specific character of a resource (Ostrom 2009; Peluso 1996), the user, the season or because of particular circumstances (Shipton and Goheen 1992). Informal rules and norms are constantly adjusted to adapt to changing economic, environmental, social and political circumstances, including formal policies and laws (Berry 1989b; Berry 1992; Elmhirst 2011; Peluso 1996).

However, people's behavior or access in practice, what we call 'accessing' in this paper, commonly deviates from the informal rules and norms of access (Agrawal and Gibson 1999; Gengenbach 1998; Leach *et al*. 1999). Accessing is a dynamic and constantly re-negotiated process (Berry 1989b; Gengenbach 1998; Shipton and Goheen 1992). Accessing may be case-specific, as every village or region has its own norms and resource endowments, but patterns can be identified that apply beyond a specific case especially when considering specific dynamics of, for example, gender or power distribution (Berry 1989b; Meinzen-Dick *et al*. 1997; Ribot and Peluso 2003).

Access in the Context of Resettlement

Development projects such as dams and conservation areas often lead to displacement of people. Resettlement commonly leaves people worse off than before (Brockington and Igoe 2006; Cernea 1997; Schmidt-Soltau and Brockington 2007). The risk of losing access to common property resources and the risk of landlessness in post-resettlement have been identified as problems common to many resettlement projects (Cernea 1997; Kibreab 2000; Koenig and Diarra 2000). In an attempt to mitigate the risk of impoverishment caused by resettlement, the World Bank (WB) developed a policy (WB OP 4.12) that calls for fair compensation, and upholds that resettled people should be provided with development opportunities. The provision of conditions for people to benefit from resettlement requires careful planning and negotiation of compensation on the part of those responsible for enacting the policy (World Bank 2004). The policy is primarily concerned with how to determine how much (quantity) of which

resources (quality) each person should get. Access is not explicitly addressed except in a footnote that says:

> For losses that cannot easily be valued or compensated for in monetary terms (e.g., access to public services, customers, and suppliers; or to fishing, grazing, or forest areas), attempts are made to establish access to equivalent and culturally acceptable resources and earning opportunities. (World Bank 2001:3, endnote 11)

How 'attempts to establish access' are to be made is unclear. Formal entitlement to resources provided through the national government in the form of compensation for resettlement is ineffective if access to resources is denied in practice (Sikor and Lund 2009).

The Study Site and Context

The LNP, located in Gaza Province in southern Mozambique, forms part of the Great Limpopo Transfrontier Conservation Area (GLTFCA) (Fig. 1). The GLTFCA connects the Kruger National Park in South Africa with Gonarezhou National Park in Zimbabwe and Zinhave, Banhine and Limpopo National Parks in Mozambique. Of the 27,000 people who reside within the borders of the LNP, 7000 live in villages along the Shingwedzi River that runs through the center of the park. These villages were designated for resettlement outside the park's boundaries in 2003 after the establishment of the park (Milgroom and Spierenburg 2008).

The South African NGO, Peace Parks Foundation (PPF), was the primary promoter of the establishment of the new transfrontier conservation area (TFCA) but major funding for the creation of the LNP and for resettlement was provided by the German development bank Kreditanstalt für Wiederaufbau (KfW) (Duffy 2006; Milgroom and Spierenburg 2008; Spierenburg and Wels 2006; Wolmer 2003). The World Bank Operational Policy for Involuntary Resettlement (WB OP 4.12) was adopted as the guiding framework for the resettlement initiative.

A pilot project involving the resettlement of two villages, Nanguene and Macavene, originally located on land that became the LNP, was intended to establish precedents for the resettlement of the remaining six villages. Nanguene, a small village of approximately 70 people, was resettled in 2008 as a new neighborhood of the village of Chinhangane, an existing village that lies a short distance outside the park boundaries (Fig. 1). Nanguene was expected to share the land and resources with the host village Chinhangane. The compensation package for resettlement included one brick house per nuclear household, assistance with materials to rebuild additional houses, 1 ha of arable land per nuclear household, compensation in cash for remaining land lost, fruit tree saplings, seed and a small amount of cash to ease transition (Ministry of Tourism 2007). This compensation package was designed by people who knew both the land, livelihoods and the individual residents of the villages well and it was approved by the World Bank. Although 1 ha of land is not enough to provide the food needed by a family (Milgroom and Giller 2013), more land was not granted to the resettling residents as all land already had a customary owner (Milgroom 2012).

All land in Mozambique belongs to the state. A law was passed in 1997 that recognizes customary tenure and requires approval by the community for use of village land by external parties, but no land can be purchased. Residents in this area depend heavily on natural resources for their livelihoods (Milgroom and Giller 2013). Agriculture and livestock rearing are the most important activities. Most residents were born within the area but have experienced a turbulent history of upheaval because of floods, disruptive social policies and war (Lunstrum 2007). Despite these previous resettlements their sense of connection to the land within the park has not diminished, partly because access to resources is heavily dependent on one's place of birth or that of one's relatives (Witter 2010).

Methods

The objective of this study was to explore the relationships among quality and quantity of and access to resources in order to assess why resettled residents struggled to survive in their new environments. Therefore we studied the quantity and quality of the available resources as well as the rules and norms of access and the dynamics of accessing in both the pre- and post-resettlement context.

Understanding Rules and Norms of Access and *Accessing* Natural Resources

Research was conducted between December 2006 and June 2010 within and around LNP. To investigate both the rules and norms of access as well as actual process of accessing resources in the pre-resettlement location we employed participant observation and repeated in-depth interviews in the village of Nanguene for 24 months. We observed livelihood activities and documented the residents' negotiations with LNP staff and the host village about the conditions for post-resettlement. During this time we investigated the rules and norms of access by asking men and women in the resettling and host village how they gained access to each field and grazing area they used, whether the resource was shared with the household, the village or other villages. We observed and participated in collection trips with women to fetch water and collect fruits and on fishing expeditions and with men to get construction materials. In each case we asked how they knew

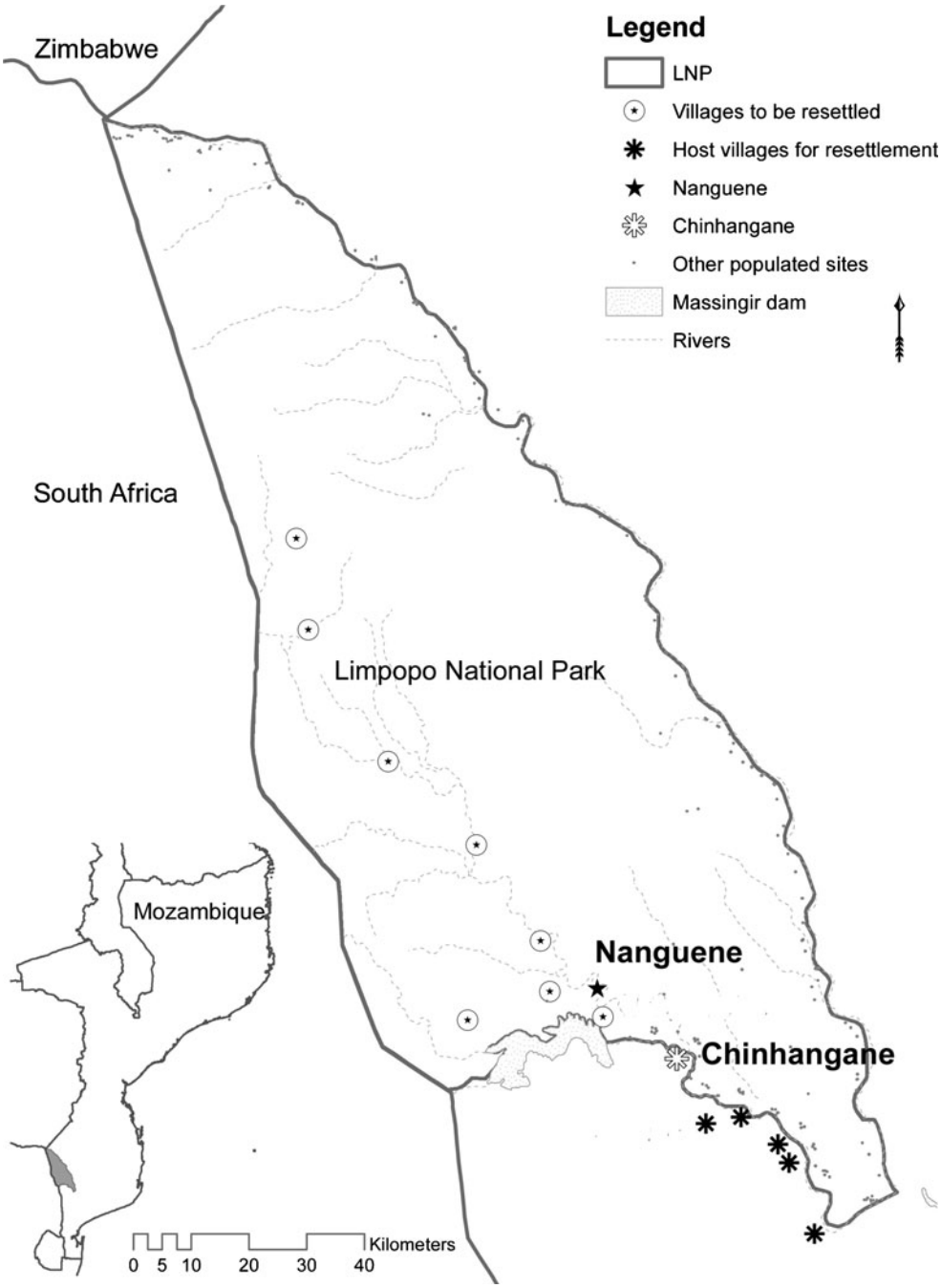

Fig. 1 Map of the study area highlighting the location of the resettlement villages, their proposed resettlement locations (host villages) and the location of Nanguene before being resettled to Chinhangane in 2008. (Map credit: Jessica Milgroom)

they could use the resources they were using, and how they would access each of the four resources if they were new to the village. We compared our results with other studies carried out in the LNP (Elderman 2009; Leonardo 2007; Shipton 1994; Shipton and Goheen 1992; Verbeek 2009; Witter 2010). After resettlement, observations were continued with the village in the resettlement location of Chinhangane, recording each resettled household's process of accessing resources in the new location. In this period we systematically asked the same questions posed before resettlement and followed up on cases where people had difficulty accessing resources with in-depth interviews. We collected and analyzed LNP documents associated with the resettlement project, and carried out repeated, in-depth interviews with LNP staff.

Analysis of Quantity and Quality of Natural Resources

We assessed the quality and quantity of the natural resources in the pre-resettlement location of Nanguene (23°47′S, 32°07′E) and in the post-resettlement location of Chinhangane (23°54′S, 32°15′E) using a variety of methods. We chose to analyze the quantity and quality of water, agricultural fields,

grazing and forest resources because these were ranked to be the four most important natural resources by the resettling residents (Milgroom and Giller 2013).

Spatial Data Analysis

A land cover map developed by PPF based on multi-season Landsat TM imagery from 2005 and 2006 was used to determine areas covered by different types of vegetation within and around each village (GeoterraImage Ltd 2008). The accuracy and the relevance of the classification used in the map for local resource use was validated through ground-truthing, as described for each resource below. The boundaries of the villages were determined using a combination of spatial data collected while walking with village residents, discussions about the boundaries with village elders, and through secondary sources. The boundaries of Chinhangane traditionally have been contested and are not legally delimited, but the approximate boundaries recognized by the villagers were used for our study. The boundaries of Nanguene were not legally delimited, contested, nor well-known locally; therefore, for the purpose of this study, we defined its boundaries based on the areas of resource use. Spatial data were collected while accompanying residents in their daily activities using GPS (Garmin GPSMAP 60) and processed using ArcGIS 10.

Water

We observed and interviewed key informants about the presence of water all year around, and measured the distance from the center of the village to the nearest source of sweet water, as well as the nearest source of any water. We assessed the quality of the water based on whether or not it was considered too salty to use for consumption (drinking or cooking).

Agricultural Fields

To assess soil quality we took soil samples (0–20 cm depth) in Nanguene from three different cropping areas. Soil was tested for pH in water using a 1:1.25 soil to solution ratio, cation exchange capacity (CEC) using the ammonium acetate method (Reeuwijk 2002), texture using the modified pipette method (Gee and Bauder 1986), % soil organic carbon (SOC) using the Walkley-Black procedure (Black 1965), total nitrogen (N) using the Kjeldahl method (Bremner and Mulvaney 1982), phosphorus (P) by Olsen extraction (Olsen *et al*. 1954), potassium (K) by flame emission spectrophotometry (Reeuwijk 2002). For Chinhangane, soil analyses were provided by the Mozambican Institute for Agricultural Research (IIAM).

To determine the total area of cropped land, we walked the perimeter of 282 ha in the major cropping areas in Nanguene and Chinhangane in 2009 and used these spatial data to validate the land cover map for agricultural land. Of the total area, 35 % of waypoints corresponded with the dryland agricultural fields class, and 31 % with the 'wetland seepage/pan' class (see Fig. 2). We confirmed that the residents had fields on the often dry wetland seepage/pan areas and therefore we joined these two classes to represent the total area with agricultural fields. The remaining 20 % fell in open woodland and bushland potentially indicating clearing of forest between 2005, when the images were taken, and 2009, when ground-truthing was done.

Whether the area available for cropping in the post-resettlement location was sufficient for both the resettling and host villagers was determined by dividing the total area judged to be 'adequate' and 'moderately adequate' for cropping, as determined by Rural Consult (Rural Consult 2008:39) by 1.37 ha per person. This value was determined based on the area necessary for a household to be food secure given the rainfall variability of the region (Milgroom and Giller 2013).

Grazing

To determine the quality and quantity of grazing resources in both locations we walked with local shepherds along their normal routes in the dry (October) and rainy season (January) in Chinhangane, and in the dry season only in Nanguene, recording the routes using GPS. Quadrats of 0.25 m^2 were placed every 100 steps along the route and standing biomass (excluding bushes or trees) in each quadrat was collected. The fresh weight of the collected biomass was recorded in the field and dry matter was attained after drying the samples in the laboratory (g/0.25 m^2). The distance from each grazing area to the village, and to water holes for the livestock, was measured.

We consulted studies on species composition and grazing quality to determine overall the grazing quality of each land use type defined by the land cover map. We overlaid 231 points from the recorded grazing routes to validate the land cover map for accuracy. Of these points, 172 (74 %) corresponded to the 'open woodland/ bushland' class, and another 24 points (10 %) to the 'bushland and thicket' class. These are the classes we used to calculate grazing area (Fig. 2). Bushland and thicket and seasonal bushland and thicket were considered to have higher quality grazing than open woodland/bushland because of the greater prevalence of high value grazing species (Elderman 2009; Rural Consult 2008; Stalmans *et al*. 2004).

To determine whether or not the grazing area in the post-resettlement location was sufficient for the livestock from both Chinhangane and Nanguene, we calculated carrying capacity based on an annual production of dry matter (DM) of 1,560 kg/ha (Mfitumukiza 2004; Pagot 1992; Timberlake 1988; Timberlake and Reddy 1986). We considered that each tropical livestock unit (TLU) weighing 250 kg needs 2,281 kg of dry matter per year (Badini *et al*. 2007). We also considered a 50 % use efficiency of the grazing resources (Timberlake and Reddy 1986).

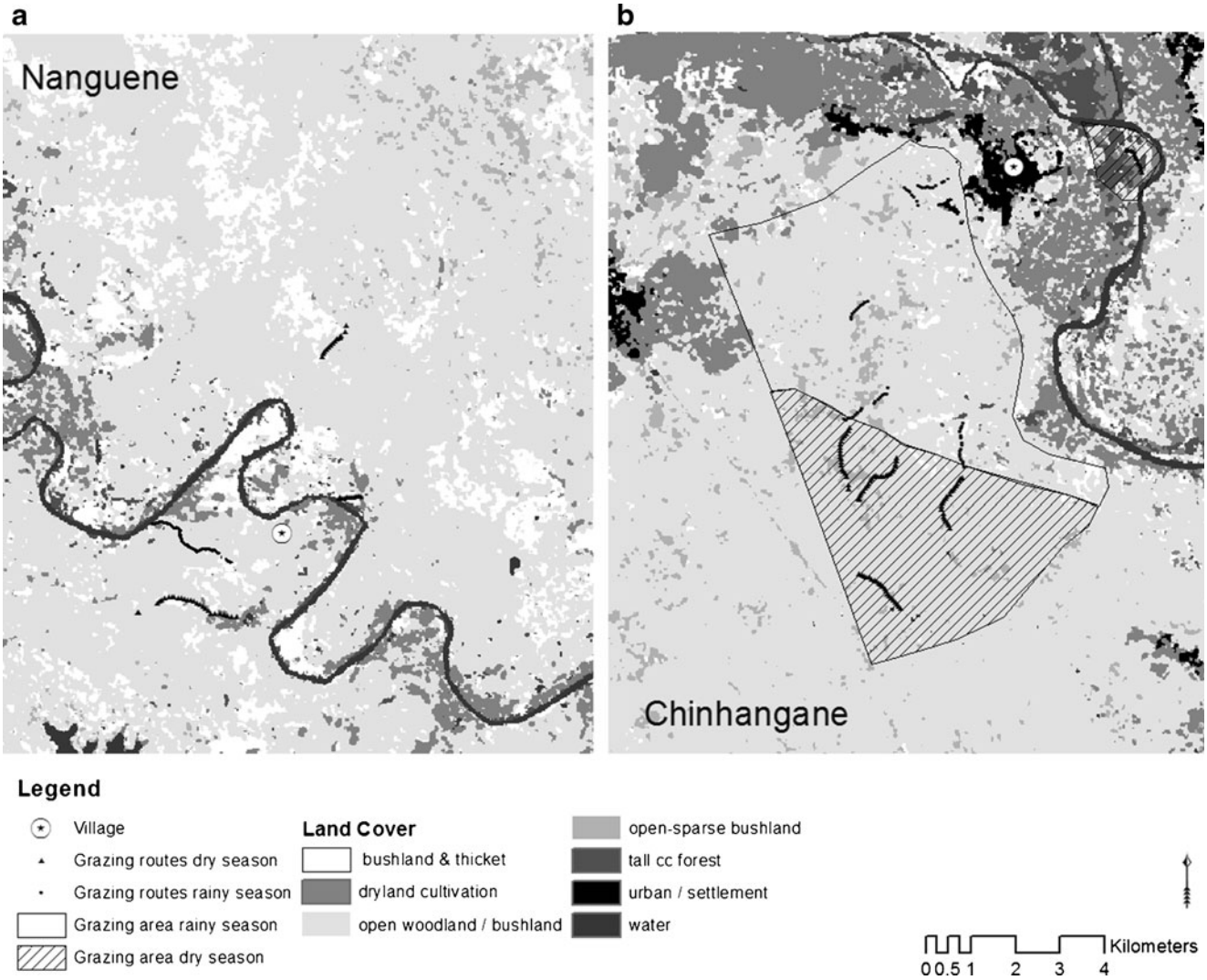

Fig. 2 Land cover maps for the Nanguene (**a**) and Chinhanguene (**b**). Grazing routes and areas in the dry season are indicated for both villages, and in the rainy season for Chinhangane. The village boundaries for Nanguene are not indicated because they did not limit grazing. The areas covered by cultivated land, open woodland / bushland, and urban settlement are larger in Chinhangane than Nanguene. (Map credit: Jessica Milgroom)

Forest

Previous studies carried out in the vicinity on the human use of forest resources provided the basis for our calculations of quantity and quality. We used the results from Verbeek (2009) to identify the most important species used for food, construction, and firewood. These results were verified through comparison with those of Witter (2010) and through our own interviews and observations. We took into consideration all the species mentioned by more than 75 % of respondents during a free-listing exercise (Verbeek 2009). We associated each of these species with a land cover class based on their reported habitats (Palgrave and Palgrave 2002; Schmidt *et al*. 2004; Wyk and Wyk 1997) and related studies (Rural Consult 2008; Stalmans *et al*. 2004; Verbeek 2009). Verbeek (2009:41) found that the riverine forest has a significantly higher number of species than the upland forest. We used the area of riverine forest as a proxy for 'area with elevated biodiversity' representing the most important forest resources used by residents.

Findings and Discussion

At first sight, the total area and the quality of resources were similar between the pre- and post-resettlement locations. However, there were differences in the quantity of higher quality resources and the quantity of resources per person and per animal unit. The area covered by high-quality grazing land and by riverine forest was much smaller in Chinhangane than in Nanguene (Fig. 2, Table 2). The number of people and livestock inhabiting Chinhangane before resettlement was

Table 2 Quantity and quality of natural resources in Nanguene and Chinhangane, specified by water, grazing resources, fields and forest

Resource[a]				Nanguene		Chinhangane		Chinhangane after resettlement	
				Per village	Per person/AU	Per village	Per person/ AU	Change for Nanguene village	Change per person/AU (Nanguene)
		Total area (ha)		6,253		7,831		7,831	
		Number of inhabitants		77		559		636	
		Number of animal units (AU)		158		857		1,015	
Water	Quantity	Water all year around (y/n)		y		y		–	
	Quality	Distance to sweet water (km)		0.5		2		−1.5	
		Distance to water (km)		0.5		0.1		+0.4	
		Closest water salty/ sweet		sweet		sweet		salty	
Grazing	Quantity	Total grazing area (ha)		5,649	35.76	6,317	7.37		−29.53
		Standing biomass in dry season (Mean kg/ha (StDev))		466 (763)	16,663	582 (681)	4,290		−13,040
	Quality	Area high quality grazing land (ha)		970	6.14	194	0.23		−5.95
		Average distance to grazing areas in dry season (km)		2.2		7.1			
		Distance to water from start of grazing area (km)		1.85		10			
Fields	Quantity	Total area of cleared fields		255	3.32	506	0.91		−2.52
	Quality	Soil quality	Sand (%)	69 (17.9)		57 (21.9)			
		Mean (StDev)	Silt (%)	17.6 (10.6)		26.8 (14.8)			
			Clay (%)	13.1 (9.5)		15.7 (7.4)			
			OM (%)	1.8 (0.7)		2.4 (1.04)			
			N (g/kg)	–		0.13(0.04)			
			P (mg /kg)	27.9(19.7)		39.73(14.6)			
			K (cmol/kg)	1.08(0.73)		1.76(0.6)			
			CEC (cmol (+)/kg)	18.6(4.95)		38.35(9.66)			
			pH	6.6(0.24)		7.25(0.42)			
		Cleared potentially irrigable land (km along river)		1.3		1.8			
		Not cleared potential irrigable land (km along river)		6		13			
Forest	Quantity	Total area of forest (ha)		5,763	74.8	6,504	11.64		−64.63
	Quality	Biodiversity (area of riverine forest) (ha)		114	1.48	186	0.33		−1.19
		Area for collection Nhiri, Ntoma, Nkuwa (food) (ha)		1,084	14.09	381	0.68		−13.49

Table 2 (continued)

Resource[a]	Nanguene		Chinhangane		Chinhangane after resettlement	
	Per village	Per person/AU	Per village	Per person/ AU	Change for Nanguene village	Change per person/AU (Nanguene)
Area for collection Nkanyu and Nwambo (food) (ha)	4,753	61.74	6,167	11.03		−52.04
Area for collection of firewood and construction Materials (ha)	4,660	60.52	5,750	10.29		−51.48

[a] Original land cover and vegetation classes from the Great Limpopo Transfrontier Park (GLTFP) land cover map (GeoterraImage Ltd 2008). Class names and descriptions as followed. Wetland seepage / pan: Vegetated wetland areas that are less permanent in nature than the floodplain class, which appear to be associated with riparian and seepage zone, and pan landscape features. Tall closed canopy (cc) forest: Closed canopy tall forest (or very dense woodland areas (i.e. multiple vegetation strata likely), where tree canopy is likely to be greater than ± 70 %. Dryland / subsistence cultivation: Rainfed subsistence / semi-commercial cultivation activities (predominately field mosaics but may include scattered dwellings) Urban / settlement: Areas of concentrated urban or settlement patterns. Closed canopy (cc) bushland & thicket: Closed – medium canopy short bushland and / or thicket areas (i.e. multiple vegetation strata likely), where shrub and bush canopy is likely to be greater than ± 70 %. Open woodland & bushland: Open canopy woodland and / or bushland , where the tree and bush canopy is likely to be between 40–70 %. Closed canopy (cc) bushland & thicket (seasonal): Closed – medium canopy short bushland and / or thicket areas (i.e. multiple vegetation strata likely), where shrub and bush canopy is likely to be greater than±70 %. Class shows a distinct seasonal canopy variation compared to the cc bushland and thicket class

seven times more than in Nanguene; therefore, the quantity of resources per person and per animal unit, assuming equal access, was much less in Chinhangane than in Nanguene even before the arrival of the resettled villagers (Table 2).

We found that there were differences among the formal access to resources presumed by the government as part of compensation for resettlement, the informal rules regarding access to resources and accessing in practice. We now turn to a more in-depth presentation of the results of each resource separately; the comparison of the quality and quantity between pre-and post-resettlement locations, the rules and norms of access in the region, and the challenges resettled residents faced in accessing each resource post-resettlement.

Quality and Quantity of Water in Pre- and Post-resettlement

In Nanguene, water was available under the riverbed—residents of Nanguene had never experienced a lack of water. In Chinhangane, water was available all year around from two sources. One source was a pump in the resettlement neighborhood, with salty water not suitable for drinking or cooking. The other was in the established village of Chinhangane, which had sweet water. Resettled residents have to travel 1.5 km farther to the sweet-water pump than they had travelled for water pre-resettlement (Table 2). Resettled residents feared that the pump would break and they would not have access to water but there was no concern that there would not be enough water if the pumps were working.

Rules and Norms of Access to Water

Water, a resource fundamental to daily survival, is shared by everyone. Residency or group membership is not a requirement to access water. A fee may be charged to those who can pay it to cover the costs of the maintenance of the well.

Accessing Water: Waiting in Line

The salty water in the well built for the resettled residents caused residents to fetch water in Chinhangane where there was only one pump with sweet water for the whole village. A monthly fee had to be paid to access this water and fetching water required the extra time that it took to wait in long lines. Many women complained of new marital conflict arising from not having enough sweet water in the household or cooking dinner too late because of the delay resulting from fetching water. This example illustrates the way in which accessing water was influenced by the quality (need for sweet water) and reduced quantity of the resource (only one well).

Quality and Quantity of Agricultural Fields in Pre- and Post-resettlement

There were no significant differences in soil quality measurements between the two villages. Both villages had adequate soil nutrient concentrations for cropping. The area of open fields was less per person in Chinhangane (0.91 ha/person) than in Nanguene (3.32 ha/person). The area of potentially cultivatable land as defined by Rural Consult (2008) occupied by existing fields (506 ha) and forest (889 ha), measured 1,395 ha in Chinhangane. Based on a need of 1.37 ha per person (Milgroom and Giller 2013), this area could accommodate 1,018 people if all the forest area were cleared. At the time of this study, in total there were 636 inhabitants including the resettled residents, suggesting there was enough cropping land in Chinhangane to accommodate residents from both villages without having to cut down more of the forest.

Rules and Norms of Access to Agricultural Fields

There is a general culture of inclusiveness and flexibility about access to land because of the central role that food production plays in local food security. This undertone of solidarity, in theory, provides everyone with as much land as they need to produce food for their household (see also Shipton and Goheen 1992; Witter 2010). Even if someone is not from the village in which she or he wishes to cultivate, it is common practice to borrow land and longer term access to fields can be attained through the village chief (see also Leonardo 2007). Survey results from October 2008 revealed that 126 people out of the total population of 559 were living in Chinhangane in order to use the fertile soils of the river valley, although they were not from the village. These individuals came without their families to cultivate on borrowed land, and at the end of the season returned with their harvest to their original village.

The agricultural fields of the permanent residents of Chinhangane were either inherited, opened, borrowed or received as a gift (see also Witter 2010). Out of a total of 154 fields owned by 63 households interviewed, 58 % of the fields were inherited, 34 % were opened by the owner, 2 % were borrowed and 6 % had been received as a gift. Only the male household heads or widows had inherited fields, while all categories of owners except widows or female children opened fields.

Accessing Fields: A site of Traditional Ceremonies

In compensation for resettlement, each resettled nuclear family was allocated 1 ha of land in Chinhangane. An area of 18 ha was cleared by the LNP as one contiguous block for the18 nuclear families from an area that was previously dense forest. After the fields were officially handed over, Nanguene residents discovered that they encompassed a site with traditional spiritual value for Chinhangane residents. A legendary healer had been crippled by ancestral spirits while performing a ceremony at this site. Chinhangane residents believed that anyone who planted crops there would also become crippled. The LNP staff responsible for resettlement reported that they knew that the plowed land contained a place of ceremony for Chinhangane but they had still accepted the land as the site for Nanguene's fields. The sacred site – in the center of someone's field – was simply marked with cinderblocks. It was widely believed by the Nanguene villagers that Chinhangane offered them this location precisely because it would not be used by people from Chinhangane. Resettled residents who had secured other fields only planted in the fields allocated by the park last, or did not plant them at all. Households that had to plant on these fields did so in fear.

This experience provides evidence of how the quality of a resource is socially-constructed, based on the intended resource use and who evaluates the quality; a culturally valuable resource has more gradations of quality when evaluated by a resource user than when evaluated by someone who is not familiar with the resource (Shipton and Goheen 1992). For example, park staff apparently did not believe that it would be a problem that the dryland fields provided in compensation for resettlement were cleared on land used by the host village for traditional ceremonies. Physically and legally the residents had been granted access to the fields but their fear of repercussions prevented their access to the land in practice. Perceptions of quality can change through access to new information or other social, environmental or economic changes. For example, until the people realized that their fields encompassed a site of traditional ceremonies, they were unafraid to plant there.

Accessing Fields: Only for Family

The cropping system in the Massingir District is based on extensive farming of large areas (Milgroom and Giller 2013). Before resettlement, each household in Nanguene had 5–18 ha for cropping and field size was limited only by their capacity to clear and crop it (Gengenbach 1998; Milgroom and Giller 2013; Witter 2010). The one ha provided as compensation for resettlement was not sufficient to fulfill household food needs and resettled households had to find additional fields on their own. The resettlement staff reported in interviews that they expected that Nanguene households would not have a problem doing so.

In the first cropping season many of the resettled households borrowed fields; some cleared the borrowed fields only to be evicted later, but none secured fields in Chinhangane on a permanent basis. A year and a half after resettlement, only half of the resettled households had secured permanent fields, which were significantly smaller than those they had before resettlement. Permanent access to fields was only achieved through family connections, marriage, by paying money or by

requesting land from the leader of the neighboring village; no fields were secured through the leader of the host village. Those with family ties in the host village managed to access more and larger fields than others. Four months after resettlement, half of the households, including the leader of the village of Nanguene and all others that had no family connection with the 'owners of the land' in Chinhangane, went back into the park looking for cropland and for grazing. They were granted this land by the leader of a village inside the park who had kinship connections with the leader of Nanguene (Milgroom 2012).

This example illustrates how resettled residents faced challenges of accessing land despite generally inclusive rules and norms of access. The resettlement of a whole village, albeit a small one, implied the influx of a large number of people needing to access land. The difficulty faced by some households in securing fields may have been the result of a response of the village to feeling that their resources were threatened by the newcomers (see also Gengenbach 1998). Despite the availability of what would be sufficient quantity and quality of land for all the existing and resettled families in the current moment, residents were concerned about the future and having enough land in the family to be able to provide for the next generation. Many people lend or cede land to others, but mainly to people, for example family members, from whom they can reclaim or borrow land in case of need (Gengenbach 1998). Therefore resettled families of the same lineage as the existing families in Chinhangane had more success in securing fields.

Quality and Quantity of Grazing Resources in Pre- and Post-resettlement

In the rainy season forage was available close to the village, but livestock walked increasingly longer distances during the dry season to find grazing. There was no significant difference between the villages in standing biomass per ha of grazing grass in the dry season in the grazing areas used (kg/ha). However the grazing areas and water points were three and five times further away, respectively. The areas near the village of Chinhangane had already been overgrazed and were no longer suitable for grazing until the next rains (Fig. 2). Even in the rainy season the distance to grazing resources in Chinhangane was greater than in the dry season for Nanguene (Fig. 2). There was four times more standing biomass per animal unit in Nanguene because of the elevated numbers of livestock in Chinhangane (Table 2). The area of high-quality grazing was five times greater in Nanguene and 26 times greater when expressed per animal unit. We estimated that the grazing land in Chinhangane can accommodate 2160 TLUs; Chinhangane and Nanguene residents combined owned 1131 TLUs after resettlement. Therefore, the total grazing resources in Chinhangane were sufficient to support the livestock from both villages.

Rules and Norms of Access to Grazing Land

Grazing land is a resource shared by the whole village (see also Elderman 2009). Village boundaries are expected to be respected although boundaries are often contested. Agricultural fields, although privately managed during the cropping season are common grazing areas when there are no crops standing. The leader of the village, together with the village elders, decides when cattle are allowed to graze freely.

Accessing Grazing Resources: Cattle Theft

Inside the park Naguene residents had experienced little cattle theft. In the dry season, when the good grazing areas were further away from the village, the herds of cattle were left alone in the forest to graze for a week at a time, sometimes for the duration of the whole season. In Chinhangane, however, grazing resources were available in the post-resettlement location in sufficient quantity, and appropriate quality but cattle theft was a major problem and residents did not leave their cattle unattended. This implied that a household either had to hire someone to graze the cattle or keep a child out of school. Households that did not have children of appropriate age to graze cattle, or that could not afford to hire someone, effectively did not have access to grazing resources. This example shows how in some cases accessing was challenging, not because anyone was controlling the access as in the case of accessing land for farming, but because of a contextual factor (or lack of an access mechanism) that they could not overcome.

Quality and Quantity of Forest Resources in Pre- and Post-resettlement

The tree species most important for food were, in order of importance (local names in parenthesis): *Sclerocarya birrea* (nkanyu), *Berchemia discolor* (nhiri), *Diospyros mespiliformis* (ntoma), *Manilkara mochisia* (nwambo) and *Ficus sycomorus* (nkuwa). Important species for construction were: *Colophospermum mopane* (xanatsi/gunwe) and *Androstachys johnsonii* (simbiri), and for firewood: *Colophospermum mopane* (xanatsi/gunwe) and *Combretum apiculatum* (xikukutse). Three of the trees used for food were found in the riverine habitat and in the bushland and thicket forest, greater areas of both of which were found in Nanguene (Table 2). Areas for the collection of timber for construction and firewood were larger in Chinhangane. However, the total area used for collection of forest resources, the area of high biodiversity, and areas for the collection of key species for food, construction and firewood, were all larger per person in Nanguene (Table 2).

Table 3 Mechanisms of access operating in post-resettlement as residents of Nanguene attempt to gain and maintain access to resources, in Chinhangane, Massingir. Some mechanisms also serve to limit access to resources

	Mechanism	Water	Grazing	Fields	Forest
Rights based	Legal	A new well was built for Nanguene in compensation for resettlement	Land law recognizes customary tenure by requiring delimitation, community consultation and agreement to the use of their land	Agricultural fields were given to each household in compensation for resettlement to each household to	No compensation for loss of common property after resettlement
	Institutions	Equal access to water for all	Equal access to grazing resources for all	Access to fields provided to those born or married into the village or if requested from the leader	Equal rights to forest products except for some resources located on another person's current or old field
	Illegal	Theft and removal of jerry cans from the line at the well limited access to water	Land law procedure, adhered to by AWF was not by ProCana. Cattle theft limits access to grazing areas.	Some resettled residents returned to an areas inside the park to open new fields	Deforestation by illegal charcoal producers, limited access to forest for other uses
Structural and relational	Technology	Well and pump provides access to water where there are no other sources or water is far away	ProCana used GPS, maps, and a tractor to mark and claim land	Infrastructure for irrigation allows for agricultural production without rain. This added value of the land close to the river limited access to land for irrigation for Nanguene.	Cart for transporting wood, fishing line for getting fish from river facilitates access to these resources
	Capital	Fee for residents to use water from the well	Used to negotiate rights of use of land with government, village leaders, and to stake claims on land (payment of tractor, etc). Capital (a small animal per year) used to hire herders to protect livestock from theft.	Some households paid fees to get access to dryland fields both in Chinhangane and back inside the park.	Used to get licenses to produce charcoal, to buy fishing tools
	Markets	If the well is broken, those with a cart or tractor can sell water	Biofuels boom led to ProCana's investments.	Fields cannot be legally purchased, limiting access for those who did not have necessary social relations to access them through customary mechanisms	–
	Labor	Time to wait in line at the well for water	ProCana controlled potential labor opportunities and used them to bribe district government and gain support. Available household labor to protect from cattle theft facilitates access to grazing areas	Labor available to clear fields increases access to land for agricultural production	Labor of preparation of *nkanyu* drink gives access to social reciprocation, favors. Labor necessary for collection of firewood and construction material in faraway locations
	Knowledge	–	Tinkering with information about delimitations increased possibility to access land	Knowledge of the healer who was crippled on the land where fields were allocated limited people's capacity to cultivate there	Information about where fruit trees that are not on someone else's field are increases access to fruit. Knowledge about distant kinship ties with a resident of the host village can facilitate access to *nkanyu*
	Authority	–	Ministry of Agriculture, Ministry of Tourism, national, provincial, and district administrators and village leaders	District administrator, park, local authorities incapable of securing land for irrigation for Nanguene.	Park staff facilitated the cutting and transport of posts from Nanguene to Chinhangane

Table 3 (continued)

Mechanism	Water	Grazing	Fields	Forest
		all involved in granting ProCana rights to village grazing land	Leader of Chinhangane also refused to grant more dryland fields to Nanguene residents	
Identity	Only women get water. Resettled residents were targeted at the well	Important political figures supported ProCana and facilitated their access to land.	For being a member of the resettling group access to land was both facilitated (1 ha per household allocated) and limited (no one wanted to provide Nanguene with land for irrigation)	Identity as a resettled person limited access to *nkanyu* ceremonies
Social relations	Friends or family members protect other's jerry cans and place in line at the well	Patronage relationships between leaders and government officials and between government officials and ProCana facilitated access to land for ProCana	Kinship ties provide preferential access to land	*Nkanyu* ceremonies key to integration (social lubrication) and get access to other resources

In Chinhangane, there was sufficient quality and quantity of resources to support the needs of the resettlement and host villages. In times of extended drought - a recurrent phenomenon - forest products become important sources of food for people (see also Verbeek 2009; Witter 2010). At these times, the extra resources that had been available in Nanguene are not available in Chinhangane. This may increase the vulnerability of resettled residents to drought.

Rules and Norms of Access to Forest Resources

Forest resources are also shared by the whole village. Fruits, firewood, construction wood, plants, fish or game can, in theory, be collected by anyone in the natural forest (see also Verbeek 2009). However, some forested areas are re-growth on former cropped land, and some natural forest areas belong to a particular household for future use, or to a charcoal-maker. In these areas, collection of some resources is restricted and permission must be obtained (see also Witter 2010).

Accessing Forest Resources: Resettling with Construction Material

In addition to receiving a brick house, resettled residents were to receive construction materials to build the additional houses typically constructed around their compounds. Compounds are commonly composed of between three and ten houses, depending on the size of the family. The area around Chinhangane did not have enough forest suitable for harvesting construction materials (*Colophospermum mopane* was the preferred tree), partly because of charcoal production that began in 2004 in earnest when the forest was divided into plots and allocated to various charcoal-making teams. Only one-sixth of the area per person for collection of wood was available in the post-resettlement location and there were no longer sufficient trees in the vicinity for the needs of the village. The trees that were available were not accessible for construction because of their high value for charcoal. Nanguene residents were informed that they should cut all the posts that they should need in the forest near Nanguene before resettlement. We recorded the number of posts prepared for construction of houses after resettlement, and the size of the posts that each household in the resettling village cut down. In addition, they dismantled their granaries, houses and kraals and gathered still usable material to be transported to the resettlement site. In total 2041 new trees were cut and 976 old posts were kept as of October 2008. In this case, both the quality and quantity of the resource influenced the dynamics of access in practice and played a part in shaping resource use. The high value of the trees for charcoal reduced the quantity of the trees available for firewood, which decreased facility of accessing in practice because of resource control exerted by charcoal makers over certain areas, as well as the increased distance to the firewood that was freely accessible to all.

Accessing Forest Resources: 'Cultivating Kinship' Through Nkanyu

Resettled residents were provided with fruit trees to replace those in their previous homesteads but they were not compensated for loss of access to common resources such as the forest and non-timber forest products (Ministry of Tourism 2007). They were expected to access these resources on the same terms as the existing residents of the area.

After resettlement, however, resettled residents expressed their despair about not having access to a particular species of high cultural importance, the *nkanyu* tree (*Sclerocarya birrea*). These trees are located primarily on currently cultivated or former fields and are accessible only to the owners or certain family members (see also Witter 2010). Since Nanguene residents had been allocated land that did not have *nkanyu* trees, and had not yet established rights to collect fruit from the land of distant family members in the host village, they had no way to collect *nkanyu* fruit. *Nkanyu* fruit is used to make an alcoholic beverage for a harvest ceremony (Jan–Feb). The seeds are collected and eaten throughout the year as an important source of food during the dry season when other sources of protein are scarce. However, interviews revealed that the despair expressed by residents was not about the fruits themselves, but about the loss of the opportunity to share in the cultural ritual of making and drinking *nkanyu* beverages. Traditionally each household collects fruit, makes the drink and invites friends and neighbors to share it. The next day another household will do the same, and everyone enjoys the drink from the fruits of each other's trees. The drink is not supposed to be sold, therefore the only way to access it is to make it or through social connections. Because of the low density of trees in the natural forest, without *nkanyu* trees on their new fields, resettled residents were not able to make their own; and they were not invited to join in others' drinking parties. This is because the *nkanyu* ceremonies are held in honor of the ancestors to reaffirm relationships within a lineage group (Witter 2010:259). This represented a missed opportunity to integrate with the host village. Although some residents of Nanguene had familial relationships in the host village, others did not and needed to 'cultivate kinship,' or the kind of relationships also called 'bond friendships' by Colson (1971) that could facilitate access to resources via other means (Gengenbach 1998). Some households did this through marriage, and others through developing new, or rekindling old friendships or family ties.

Analysis: Resource use is Shaped by Quantity, Quality and Access

Our findings based on a quantitative spatial analysis of available resources suggest that there were enough grazing resources and area for agricultural fields of sufficient quality in the resettlement location to support both the host and resettling village at the time of resettlement. However, by taking access into consideration, this conclusion changes dramatically. After

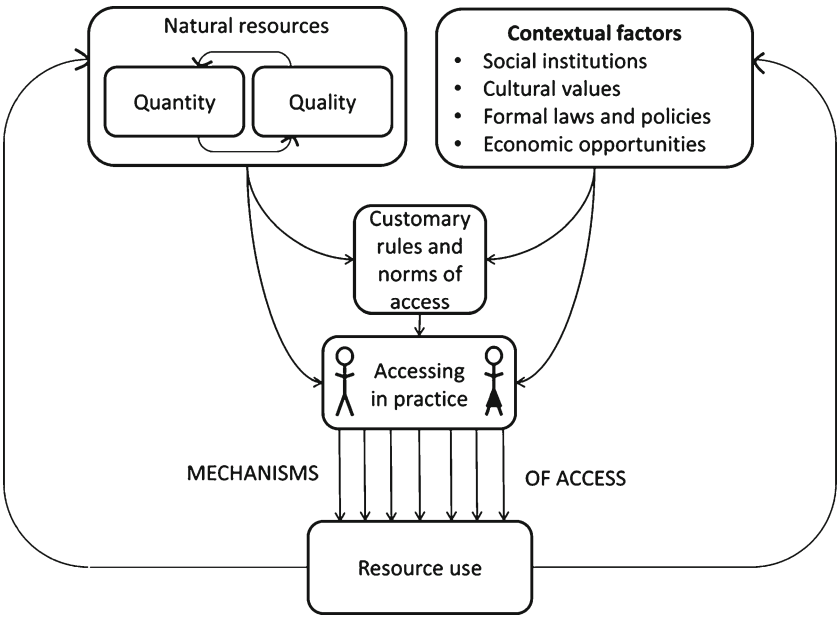

Fig. 3 The combination of the quantity and the particular resource sets the outside limits of the potential use and function of a resource. This, together with the social institutions and cultural values, formal laws and policies and economic opportunities shapes the informal rules and norms of access. Individual or household access in practice, or accessing, depends on the resource, the user, the season, etc., and is mediated through multiple mechanisms of access. Accessing is different from resource use in that it can include accessing a resource for reasons other than resource use, but it ultimately determines resource use. Resource use then influences the quantity and quality of the resource as well as the social, cultural, economic and political contexts

resettlement, despite the availability of sufficient resources, as well as the apparently inclusive rules and norms of access in the host village, the resettled residents faced major challenges to access the resources they needed (Table 3). This occurred despite a carefully planned resettlement action plan that was approved by the World Bank. The resettlement action plan and compensation package was designed by authorities and consultants who were well aware of the cultural and geographic specificities of the resettlement case. This suggests that while it is extremely important to make case-by-case evaluations when planning interventions such as resettlement, accessing cannot be predicted simply by making a static inventory of quantity and quality of resources and the rules and norms of access. By recognizing this from the outset, potential differences between rules and norms of access and accessing in practice can be accounted for in the planning.

Our findings suggest that resource use is shaped by dynamic, changing relationships between quantity, quality and access (Fig. 3). The combination of the quantity and the quality of a particular resource sets the outside limits of the potential use and function of a resource. This, together with social contextual factors such as (but not limited to) social institutions, cultural values, formal laws and policies and economic opportunities make up the informal rules and norms of access to that resource (Berry 1989b; Peluso 1996). Individual or household access in practice, i.e., their actual accessing, depends on the resource, the user, the season, etc. (Shipton and Goheen 1992) and is mediated through mechanisms of access (Ribot and Peluso 2003). Resource use then influences the quantity and quality of the resource. The latter was illustrated in the case of forest resources in Chinhangane. Because of the use of trees for charcoal making, there was insufficient quantity of wood for firewood and construction. Resource use also influences the wider social, cultural, economic, and political contexts (Fig. 3). For example, the use of resources within the LNP as a habitat for wildlife led to the resettlement of people and the introduction of the WB policy for involuntary resettlement.

Implications for Understanding Resource Use

This study shows that commonly-used methods of spatial analysis of resources can generate a misleading image of potential resource use. This may be true even when ground-truthing is carried out, rules of access are considered and local valuations of resources are used as the basis for the research, as we did in our study. The relationships among quantity, quality and access provide a static picture of the state of the resources. While extremely useful, even such detailed analysis cannot capture the dynamic nature of accessing resources. Even a time series analysis based on the past is not likely to be helpful in planning interventions for the future unless patterns of accessing are understood.

Understanding accessing requires an approach that allows observation of negotiations among people. Surveys alone may elicit rules and norms of access that differ from accessing in practice. Many studies of natural resource access, use, management and conflicts are carried out at a scale that masks actual practice. Complementary small-scale studies based on research methods that capture actual accessing can provide insight into the dynamic relationships among quality, quantity and access that ultimately determine resource use. We recognize that there are methodological challenges stemming from the different ontological and epistemological foundations of disciplines. Natural scientists are more likely to study quality and quantity of resources and social scientists to study access, yet both perspectives are needed to understand the dynamic, interwoven dimensions of natural resource use.

Conclusion

Resource use is shaped by dynamic relationships among quantity, quality and access. A static and independent assessment of quantity and quality of resources and rules and norms of access is insufficient for developing environmentally sustainable and socially equitable alternatives for resource management or for resolving conflicts over natural resources. In the case of resettlement, for example, where people's livelihoods are on the line, it is imperative to make case-specific resettlement plans to account for specificities of the quantity and quality of resources, and, as this study has shown, it is equally important to take into consideration actual patterns of accessing prior to and post-resettlement.

Further research is needed on the dynamic relationships among quantity, quality and access (Fig. 3) in other settings. While we acknowledge the methodological challenges to understanding accessing in the detail required to elucidate alternative arrangements in the context of competing claims on natural resources, it is clear that without insights derived from understanding the dynamic relationships among quantity and quality of and access to resources, it is unlikely that competing claims on natural resources can be resolved in an equitable manner.

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