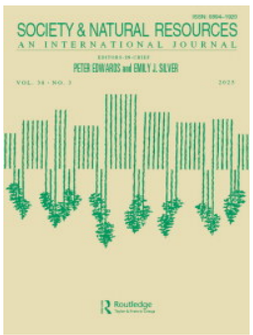

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Unpacking Natural Resource Reliance and Poverty in Northern Botswana

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ABSTRACT

Natural resources use exposes households to environmental stressors. But high usage is different than high proportional contribution to livelihood; the degree of reliance is critical for identifying vulnerable households. We contrasted differences between number of resource types harvested and their proportional contribution against wealth and vulnerability indices using 1995 and 2017 household data. In 1995, poorer households collected fewer NR types but had higher proportional contribution, and proportional contribution was positively correlated with vulnerability. In 2017, poorer households collected more NRs, but proportional contribution remained higher but its correlation with vulnerability was unexpectedly negative. By 2017, poorer households sold more NRs. Sale of NRs switched from negative correlation with proportional contribution (1995), to positive (2017). Households are vulnerable through NRs' proportional contribution to livelihood, not through range of NR types harvested. Proportional contribution highlights households at risk from environmental shocks. Market access for sustainably harvested NRs could buffer poor households.

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Climate change vulnerability; livelihood sustainability; rural livelihoods; rural poverty; semi-arid drylands; Southern Africa

Introduction

Households in rural and remote areas depend on natural resources (NRs) for a substantial portion of their livelihood, especially in contexts where engagement with cash markets is minimal. (Mertz et al. 2005; Twyman 2001). NRs significantly contribute to livelihood diversification in these settings, offering alternatives when agricultural productivity is marginal or vulnerable to failure (Ellis and Allison 2004). As rural households become further integrated into the cash economy and cash-based livelihood strategies emerge, high reliance on NRs can in fact be an indicator of poverty (Angelsen

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et al. 2008; Barbier 2010). Likewise, households that rely heavily on NRs have been found to have lower adaptive capacity and be more vulnerable to climate and other environmental changes (Adger et al. 2009; Angelsen and Dokken 2018; Choden et al. 2020; Thulstrup 2015).

NRs are often referred to as a 'safety net', supporting households when other strategies fail, or in the event of shocks (Mbiba et al. 2019; Paumgarten 2005; Salerno et al. 2020). The term 'natural resources' needs definition. In some contexts, it is taken in the broadest sense to include all components of the biophysical environment, including soils and water, and often includes agricultural activities and outputs (Campbell et al. 2002). However, in many rural contexts, it is important to separate out wild NRs, which have largely remained in the informal sector where their use is not buffered by policy interventions, while in agriculture, exposure to environmental or climate stressors is in most countries mediated by subsidies or safeguards (Dorward and Morrison 2015; Laborde et al. 2021). An extensive body of research uses the term 'non-timber forest products' to narrow the focus to exclude the basic resources underpinning agriculture (Chamberlain et al. 1998; Shackleton & Pandey 2014). However, in some instances non-*forest* resources are important, and authors have used the term 'wild NRs' as a way of differentiating wild-harvested resources from agricultural ones (Dasgupta et al. 2014; Schlesinger et al. 2015). This is the sense we mean here, truncated to 'NRs' for readability.

Empirical evidence suggests that poverty and NR use are strongly connected, and many studies show that poverty often leads to overexploitation of NRS (Barbier and Hochard 2018; Barrett et al. 2001; Dasgupta 1998). Less focus has been put on how exactly individual household poverty is influenced by NR use - although notable exceptions from political ecology identify important mediating structural factors such as markets, property rights, and governance (Cavendish 2000; Chhatre and Agrawal 2009; Holden and Bezu 2014; Ribot et al. 2006), demonstrating that the relationship between use of NRs and household economic wellbeing is more nuanced. While the linkages between poverty and NR use have been extensively studied in the academic literature, there has been a tendency to explore the relationship in terms of absolute levels of use. We argue that to fully understand whether NRs are a strategy or a safety net requires an examination of the difference between a) the extent to which they are harvested and b) the extent to which they contribute to a household's total livelihood. High levels of NRs extraction may indicate that households have greater means (transport, labor, tools) to access resources – just as they also have greater means to access other livelihood strategies (Adhikari 2005). High proportional contribution may suggest households have few alternative strategies. Furthermore, over time cash economy integration has created opportunities for commercial exploitation of NRs (Nygren 2000; Shackleton et al. 2001). The difference between commercial and subsistence use of NRs also affects the ability of households to leverage benefits from resources. We propose a typology of NR engagement as modulated by market integration, and hypothesize how these two different characterizations of NR reliance relate to poverty and vulnerability (Figure 1).

If poorer households obtain a greater proportion of their total livelihood from NRs, this makes them more vulnerable to external shocks such as extreme climate events or environmental degradation. While crop and livestock production are also susceptible

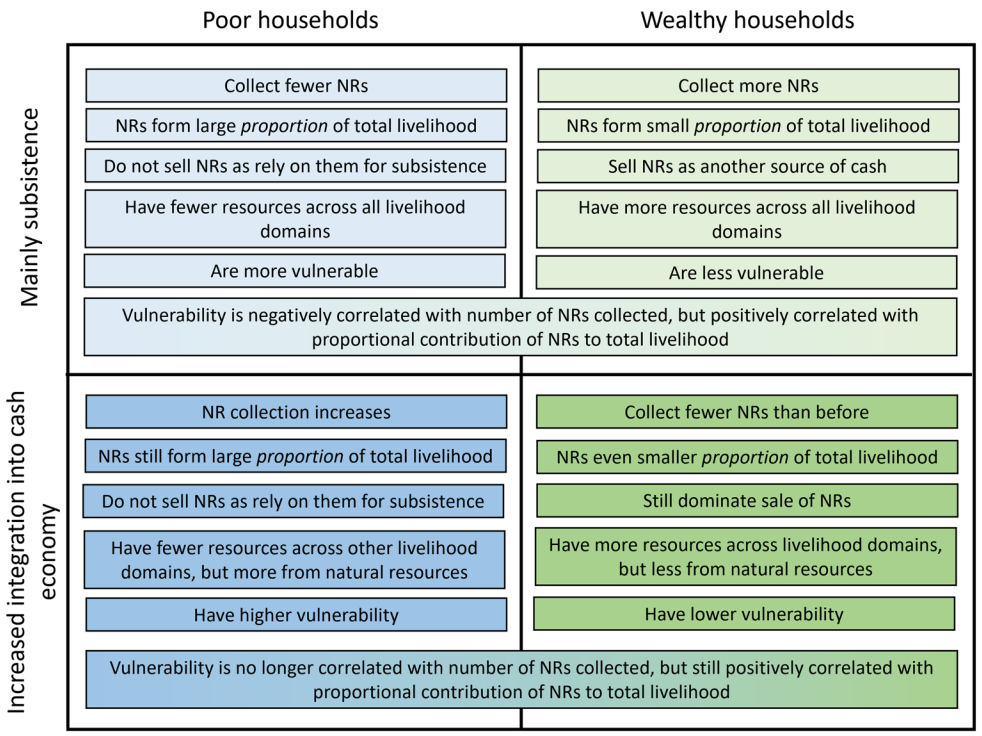

Figure 1. Typology of hypothesized relationships between poverty, vulnerability and natural resources use. Typologies assume households and communities transition from subsistence to increased market integration, albeit variably both within and between communities.

to such stressors, subsidies often function as a buffer for agricultural strategies. Teasing out the difference between total level of NR use and proportional contribution of NRs is critical for seeing beyond simplistic interpretations of the poverty – NR-use relationship, and to illuminate which households in a rural community might be most vulnerable to climate and other shocks that affect the availability of NRs (Gaughan et al. 2019; Salerno et al. 2021). The link between rural poverty, vulnerability and the proportional contribution of NRs to a household's livelihood could help shape policy that would allow NRs, especially in open access communal areas, to be managed not only for ecological sustainability, but also for greater socio-economic equity. We evaluate these typologies of NR reliance and their relation to poverty and vulnerability using longitudinal household survey data collected under two independent efforts in northern Botswana in 1995 and 2017.

To assess the difference between high levels of NR use, and proportional contribution of NRs to total livelihood, we seek to contrast these two measures against rank, representative measures of different dimensions of household wellbeing – poverty and vulnerability – that can be held constant across time. The focus here is not on whether the latter two measures are the most accurate representations of poverty and vulnerability (Stevens et al. 2023, Thiault et al 2020); it is on using accessible measures, as constrained by existing datasets, to provide reference points for evaluating the different framings of NR reliance, and the potential consequences of these framings.

Methods

Study Area

Chobe Enclave comprises a communal area of five villages located in northern Botswana, at the core of the Kavango-Zambezi Transfrontier Conservation Area, KAZA TFCA (Figure 2). The area is remote, separated from the nearest town by Chobe National Park. Development opportunities are constrained by seasonal flooding to the north-east of the Enclave, by saline groundwater conditions to the south-west, and by restrictions associated with land use in the Chobe Forest Reserve (van der Sluis et al. 2017). The area has high poverty levels and, similar to most of rural Botswana, strong dependence on government subsidies (Garekae et al. 2017, Gupta, 2013, Cassidy et al. 2023). The heterogeneous landscape provides many different NRs, such as thatching grass, building poles, and edible and medicinal plants (Salerno et al. 2018; Thakadu et al. 2020). Remoteness from large urban areas also influences reliance on NRs, as employment opportunities are few (Mosetlhi 2012). At the same time, the traditions of the dominant Subiya ethnic group include extensive NR use, such as fishing and wild-plant harvesting (Salerno et al. 2018). Land tenure is open-access and unmanaged (van der Sluis et al. 2017), and NRs are considered common property, available to anyone with the means to harvest them (Jones 2002).

Chobe Enclave is ecologically and socially distinct from Botswana's well-known Okavango Delta region, with different economic, cultural and environmental conditions (Redmore et al. 2023, Shinn 2018). Chobe Enclave is largely removed from tourism

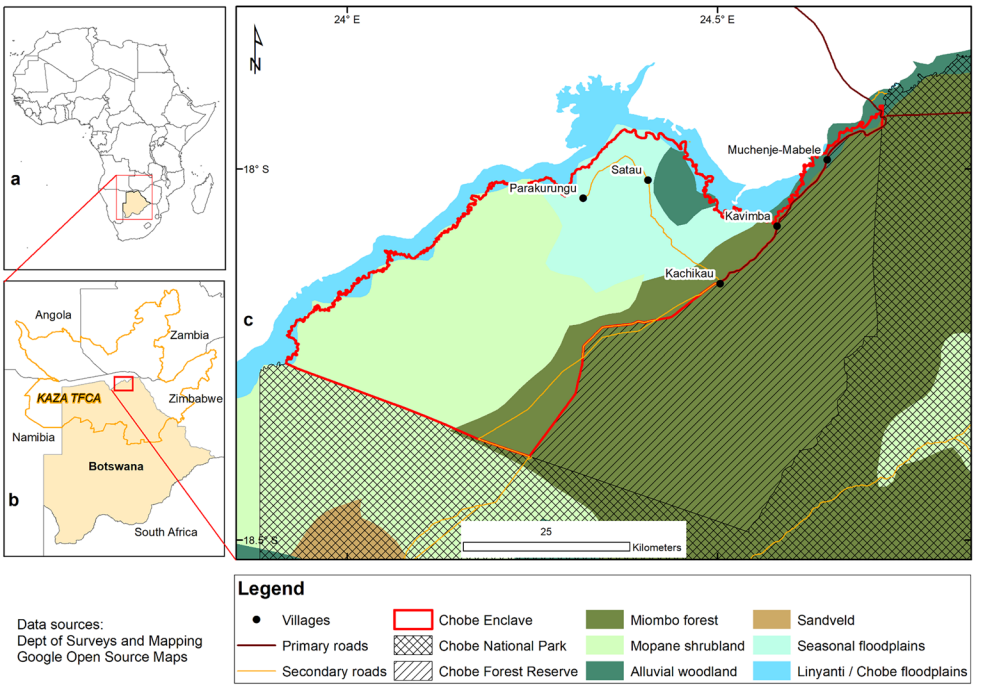

Figure 2. (a) Botswana's location, (b) Chobe enclave's location, and (c) the distribution of the enclave's 5 communities.

development and despite ongoing projects, has seen limited improvements in household wellbeing (Cassidy et al. 2023). Communities in both the Okavango and Chobe are exposed to high levels of human-wildlife conflict which we consider as part of the environmental exposure context (Gupta 2013).

Data Collection

Sample determination Repeat surveys in the same community are very rare, and consequently the opportunities to explore changing household conditions are few. We compare primary data drawn from two socio-economic household surveys conducted in 1995 (n = 283 households) and 2017 (n = 240 households). The 1995 survey was a baseline assessment prior to the introduction of the area's community-based NRs management (CBNRM) project (Ecosurv 1996). The 2017 survey was part of a three-country study of household vulnerability to climate change in the KAZA TFCA (Gaughan et al. 2019). Although the two surveys did not target the same households nor have the same primary objective, the approach to sampling and general categories of enumeration used at both time-steps was the same, and several questions were deliberately replicated in 2017, in order to create the option of using the datasets to assess livelihood change over two decades. At the same time, not all data available in 2017 were collected in 1995, limiting depth of analysis for some aspects.

In 1995, the sample size was based on recent census data showing 706 households across the five Enclave villages (Central Statistics Office 1992). Aiming for 95% confidence intervals and assuming maximum heterogeneity, calculations (after Bernard 1994) suggested a minimum sample of 248 households which was expanded to 283 based on observed in-field conditions. This total was divided proportional to village size. For 2017, the population estimates showed that a sample of 48 per village would retain the 95% confidence interval at study area level, while allowing 90% confidence intervals at village level, yielding the overall sample of 240 households.

At both time-steps, a systematic random sample selection protocol was followed (Bernard 1994). For each village section or area, the number of households estimated in that area was divided by the number of samples needed from it, to determine a 'skip' factor, i.e., the number of households to systematically skip between samples. The first household was selected by choosing a random number between 1 and the 'skip' factor value. Linear transects were walked up and down the village section, skipping the determined number of households to select the next for interviewing. Absent households were located through communication with neighbors or, if necessary, revisited up to three times before being replaced in the sample. In Chobe Enclave, most household yards are fenced, making them distinct on the landscape. However, if on arrival at a yard, preliminary enquiries suggested multiple households were in the yard, these additional households were then included in the systematic random sample.

Design and Administration of Surveys

As the 1995 survey was part of a USAID development initiative, it was not submitted for academic institutional review. Instead, the lead social scientist on the program

evaluated the instrument for ethical consideration. The 2017 survey was approved by the University of Colorado Institutional Review Board (#16–0126). Permissions from traditional authorities and government for both surveys were obtained. Survey instruments were presented in both Tswana (language of enumeration) and English (language of analysis), and are available as supplemental information. Enumerators were hired from within the study area, but with a few exceptions, did not interview within their own village to protect within-community privacy. Training of enumerators was combined with piloting the survey instruments before last-minute adjustments to language were made. A team leader was assigned to three enumerators and rotated among their interviews to ensure adherence to enumeration protocols and consistency. Completed instruments were checked in the field at the end of every day to allow for any necessary follow-up visit to the household. Informed consent was obtained from all respondents.

Data Entry

At both time-steps, every completed survey form was re-checked before data capture. Coded responses were captured in SPSS, with simultaneous preparation of codebooks. On completion of data capture, the database was cleaned, checking for input errors, and for patterns that might indicate enumerator error or bias. To ensure confidentiality, no personal identifiers were recorded in the database.

Development of Indices

The core of the analyses is based on contrasting indices representing two aspects of NR use – 1) total number of NRs harvested, and 2) proportional contribution of NRs to total livelihood – against indices representing different dimensions of household wellbeing (wealth and vulnerability). We treat these latter indices as independent and set in parallel (despite some overlap in their input variables), as the purpose is not to compare wealth and vulnerability but to evaluate how the two aspects of NR use differ with regard to household wellbeing.

We developed these measures as rank indices. While rank indices may contain less variability, they simplify the process of understanding variability within a given population (Marden 1996). This in turn, facilitates our objective of contrasting the two measures of NR reliance. All input variables refer to 'past 12 months' – capturing annual use, income, or current ownership. Time-bound indicators provide a much tighter understanding of household conditions and NR usage than do those recorded in other studies that have asked whether households generally use or have items (e.g., Garekae et al. 2017) which can lead to over-representation. All 1995 financial values were standardized to 2017 values using World Bank consumer price index values for the different years[1], and converted from Botswana Pula to US $ using the 2017 exchange rate of 10:1.

Just as there is overlap in the concepts of poverty and vulnerability (Guimarães 2007, Leichenko & Silva 2014), our indices for wealth and vulnerability share some overlap. However, we do not compare the two indices to each other. While the wealth index is used to identify those households that are income- and asset-poor or

income- and asset-rich, we believe that variations in vulnerability within these wealth categories are real and reflect the interconnectedness of the two characteristics. The four indices are 'rank' indices and not absolute value indices, allowing for data parsimony while highlighting households' relative positions. Poverty, vulnerability and the ability to seek livelihood alternatives interact with several other factors not individually addressed in this study, such as education, gender and ethnicity (Andrijevic et al. 2020; Harrison et al. 2016; Muttarak and Lutz 2014). Instead, such aspects of social and human power relations are embedded in our vulnerability index.

Given that NRs in Chobe Enclave can be freely accessed by anyone living in the area, teasing out the value a household accrues from this collective endowment is measured in terms of what is actually harvested by the household (Berkes 1985). Number of NR types harvested is a simple summation of the total number of resource types collected by each household. The selection of this as the indicator of extent of reliance on NRs is due to multiple factors. The first is theoretical, and assumes that the wider a range of resources a household collected, the less likely they were to have access to the cash economy where they could buy equivalents more easily. The second factor relates to logic and the challenge of how to compare quantities between different resource types – for example, three bundles of thatching grass vs. ten fish. The last factor is data related, because the 1995 survey did not record quantities for resources harvested, only what was sold. While quantities of individual resources harvested could be established for 2017, the point of comparison to 1995 would still need to be on the number of types of resources harvested. Although there are clearly limitations to how much variability can be captured by this first measure, the range of NRs – that is, the total number of types of NRs harvested – provides a suitable assessment of the importance of NRs to a given household. This index was created by recoding each variable of resource 1 harvested/not harvested, resource 2 harvested/not harvested, …, resource n harvested/not harvested in past 12 months to 1 = yes and 0 = no, and then summing across the variables. At both time-steps, the minimum number of resource types harvested was 0, and the maximum was 10.

Proportional contribution of NRs to total livelihood was determined by first summing all potential livelihood sources reported by each household: count of waged jobs; count of small business activities; remittance received (yes = 1/no = 0); pension received (yes = 1/no = 0); count of crop types grown; count of livestock types owned; and a count for each NR type harvested. NRs proportion was then calculated as a simple ratio of the NR types count against the total livelihood sources. The decision to use this approach to determine proportional reliance is based on the same factors as for the previous index, particularly the limitations of the 27-year-old dataset, which did not collect data on quantities. Several studies have shown that by combining current market values for resources with amounts harvested, it is possible to compare the value of NRs as an 'income' to livelihood, and compare that to 'income' from other livelihood sources (Shackleton & Shackleton 2006, Angelsen et al. 2014, Ragie et al. 2020). However, this reduces the contribution of NRs to a single value, masking whether the household derives that value from a single resource type or several. A broad range of NRs might suggest few other options, and a greater degree of dependence on the NR base. It can be argued that our approach carries the risk of overestimating the contribution from NRs, since it assumes equal weight for all strategies

regardless of any strategy's possible greater contribution. However, in the context of our remote study area, the relative weighting of NRs is similar for all households, because access to high-earning strategies such as full-time jobs is very low. Further, this proportional relationship is a way of comparing among the households of the study area, for whom external factors that may influence access to livelihood types is constant. This stronger weighting of NRs relative to other high-earning strategies may limit the generalizability of our findings and limit the potential for extrapolation to those communities that have similarly low levels of market integration, and the approach may not be appropriate in areas where there is ready access to wage employment.

A broad range and diversity of strategies, particularly in remote settings is an important way to reduce uncertainty or exposure to the unpredictability associated with environmental variability, and households with several strategies may be less vulnerable to general shocks than households with only a few (Scoones 1998, Israr et al. 2014, Sikhunyana et al. 2020). However, if the proportional range of strategies from wild NRs is high, this would make a household more vulnerable to climate or environmental shocks (Dasgupta 1998). This second index was created as follows:

Proportional contribution of NRs to total livelihood = ∑(no._resource_types)/∑(no._jobs, no._small_businesses, remittance 1 or 0, pension 1 or 0, no._crop_types, no._livestock_types, no._resource_types).

In 1995 the total number of household strategies ranged from a minimum of 1 to a maximum of 21, while in 2017 the range was from a minimum of 1 to a maximum of 18. Proportional contribution to livelihood from NRs ranged from 0 (none) to 1 (all) in both 1995 and 2017.

Wealth was determined as an order-of-magnitude index (after Brockington 2021; Cassidy and Barnes 2012) capturing both income and assets by summing: a) the household's total income from all jobs, all small businesses, all remittances, all pensions, all income from sale of NRs; b) the market rate average values for total livestock owned and cropland owned; and c) order of magnitude values for key assets. That is, all reported income for the past 12 months over the total number of income sources was summed for each household. For farmland, the area of crop fields owned was multiplied by the per-hectare market value. For livestock, the number of each type of stock owned was multiplied by the market value for that stock type. From the total list of all household assets identified at each survey wave, the current market value of that asset was assigned, regardless of how many of that asset type was owned so that, whether the household owned one or three of an item, the same value was assigned. These values were all summed into a single total for each household, which can be represented as follows:

Household wealth index = ∑(income_source_1, income_source_2, …, income_source_*n*, (ha_cropland*value), (no._livestock_1*value), (no._livestock_2*value), … (no._livestock_*n**value), (hh_asset_1*value), (hh_asset_2*value), …, (hh_asset_*n**value)).

In 1995, values in this index ranged from US$ 0 to US$ 92,138. In 2017 they ranged from US$ 67 to US$ 64,219.

Again, the wealth index is not intended as a comprehensive picture of each household's actual wealth, but to serve as a model that indicates with sufficient detail where the household falls along the community's wealth gradient.

The well-established sustainable livelihoods framework (Blaikie 2006; Heijmans et al. 2004; Scoones 1998) is a good foundation for assessing vulnerability, and it has regularly been used in the literature to do so (Vincent 2007, Knutsson & Ostwald 2023, Pandey et al. 2017). Strictly, the five 'capitals' central to the framework are intended to represent assets, but some aspects (e.g., social capital) are hard to quantify, and the term has often been more loosely interpreted to include variables that speak more to resources and capabilities (Bebbington 1999, Cassidy and Barnes 2012, Gaisie et al. 2021). Recent critiques have suggested that re-visioning the framework would better accommodate more intangible 'assets' if framed as 'relational power' (Natarajan et al. 2022). That is, the five domains contributing to livelihood sustainability are still considered valid, but only financial and physical assets would be termed 'capital'.

Within this theoretical context, we have therefore collated variables that have been shown in the literature to contribute to different aspects of household-level livelihood sustainability, grouped them under the five livelihood domains (social, human, natural, physical and financial) in the context of Natarajan et al.'s (2022) 'grounding livelihood-environment dynamics' to develop a composite household vulnerability index (Figure 3). Because we have sought to explore differences between households, inputs were limited to characteristics that varied at this level, and we explicitly excluded factors (such as infrastructure and services) that were constant at community level.

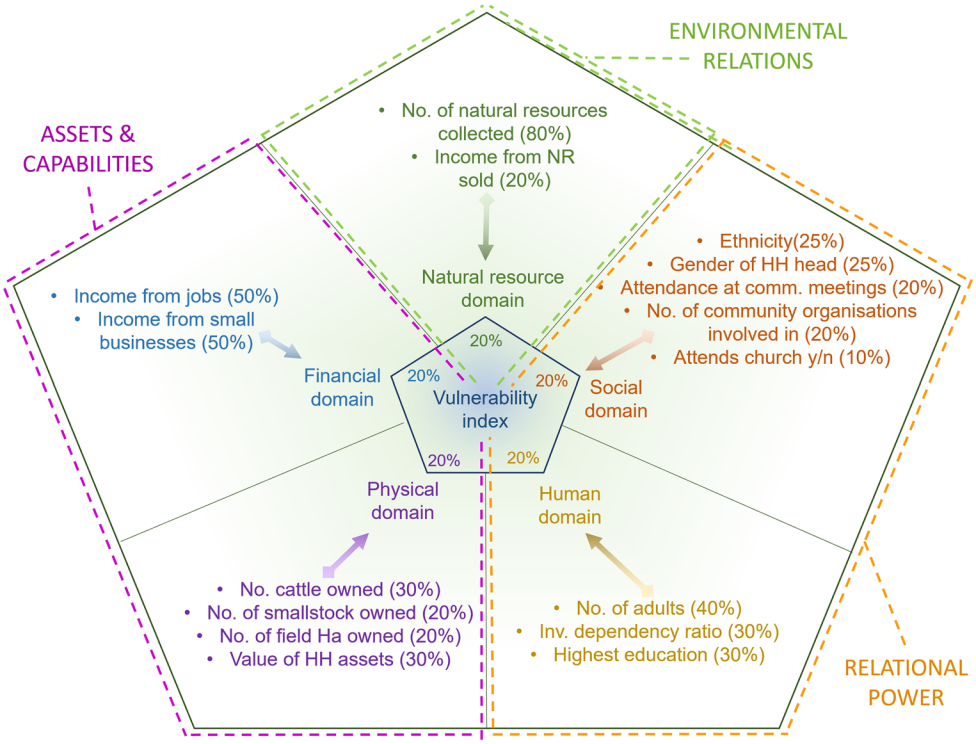

Figure 3. Schematic diagram showing weightings of input variables for the five livelihood domain indices, and the contribution of each domain's index to the overall vulnerability index. Dotted lines reference Natarajan et al.'s (2022) components of the 'grounding livelihood-environment dynamics' within their revised sustainable livelihood framework.

Table 1. Rankings for categorical variable inputs to social domain index.

Ethnicity	Gender of HH head	Attends church	Education
National majority = 4	Male-headed, resident for >6 months of year = 3	Yes = 1	University degree = 7
Local majority = 3	Male-headed, but female *de jure*, head absent for >6 months of year = 2	No = 0	Technical diploma = 6
Other ethnic group = 2	Female-headed =1		Completed high school = 5
Marginalised ethnic group = 1			Some secondary school = 4
			Completed primary school = 3
			Some primary school = 2
			No formal school = 1

The vulnerability index was calculated through a two-stage process. First, the sub-indices for each of the five domains (Figure 3) were created. For categorical variable inputs to the indices, rank values were assigned according to how each category was perceived in the study area, with highest values representing greatest contribution to that domain and lowest values representing least. Ranks used are presented in Table 1. These 'domain sub-indices' are ranking indicators that best place a household in relation to all the others in the community. They are simplified models that enable evaluation of each household's position or rank relative to other households. These sub-indices are not a comprehensive and total summing of all potential capitals, strategies or advantages within in a household, but only the major factors within each of the 5 domains that are most likely to contribute to variability within that domain's contribution to vulnerability. For example, while it may be possible to add pensions and remittances to the financial domain sub-index, in our study area these amounts are low, and variability is well captured with income from jobs and small businesses. Similarly, being remote, our study area had very low levels of either livestock or crop sales. On the other hand, adding income from NRs to the natural domain supports the evaluation of how NRs move from being a common pool resource to a private livelihood benefit, and for examination of the shift over time in the commercialization of NRs. Other study areas may require that the selection of input variables be modified to suit local conditions.

All input variables were normalized using the 'total sum scaling approach', also known as 'relative 'abundance scaling' (Costea et al. 2014, Wang 2023). This is done by subtracting the value for the household from the sum for all households, divided by the sum for all households, so that the total sum of all values for that variable equals 1, while retaining the relative proportion of each individual value. For example:

HH1_cattle_no._STD = (HH1_cattle_no. - ∑ (HH1_cattle_no., HH2_cattle_no., …, HH*n*_cattle_no.))/∑ (HH1_cattle_no., HH2_cattle_no., …, HH*n*_cattle_no.)

This normalization technique is appropriate where several indices of different data types are of interest as it provides a consistent data range that allows for greater ease of comparison among them. These normalized variables were then weighted to highlight relative importance or contribution to each domain, with weights informed by existing examples from region and our understanding of the area (Cassidy and Barnes 2012; Vincent 2004, Vincent 2007), and each was calculated as follows:

Financial = ∑((inc._jobs_STD*80%) + (inc._smllbiz_STD*20%))

1995 range was 0.000 to 0.742; 2017 range was 0.000 to 0.583.

Physical = Σ((no._cattle_STD*30%) + (no._smllstock_STD*20%) + (Ha._field_STD*20%) + (asset_val_STD*30%))

1995 range was 0.000 to 0.447; 2017 range was 0.000 to 0.476.

Human = Σ((no._adults_STD*40%) + (inv_dep_ratio_STD*30%) + (Highest_ed_STD*30%)

1995 range was 0.008 to 0.661; 2017 range was 0.020 to 0.624.

Social = Σ((ethnicity_STD*25%) + (Gender_HHH_STD*25%) + (No._times_att_comm-meetings_STD*20%) + (No._comm_orgs_in_STD*20%) + (Att_church_STD*10%))

1995 range was 0.030 to 0.851; 2017 range was 0.079 to 0.732.

Natural = Σ((no._NR_collected_STD*80%) + (inc._NR_sales_STD*20%))

1995 range was 0.000 to 0.800; 2017 range was 0.000 to 0.821.

The second stage of developing the vulnerability index was to sum each livelihood domain index with equal weighting, and then to invert the output to be more intuitive, since higher totals mean lower vulnerability. To invert the index, 1 was added to the maximum sum across all domains to create a constant, and each household's summed value was subtracted from that constant.

Household vulnerability index = (Σ(FinDom + PhysDom + HumDom + SocDom + NatDom) *max* + 1) - Σ(FinDom + PhysDom + HumDoim + SocDom + NatDom)

1995 ranged from 2.886 for most vulnerable to 1 for least vulnerable; 2017 ranged from 2.665 for most vulnerable to 1 for least vulnerable.

While it may at first appear circular to include variables for NRs in the wealth and vulnerability indices, this allows for evaluation of the relative or proportional importance of these components of the indices (cf. Chen et al. 2017 regarding analyzing proportions)[2]. Tests with null and random models show no correlations.

Analysis

Analyses focused on correlations and comparisons of the wealthiest 10% and poorest 10% of households (Bishop et al. 1995; Monino and Sedkaoui 2016). The first set of analyses were t-tests focusing on the extent of harvest and sale of four key NRs (firewood, thatching grass, fish, and edible and medicinal wild plants) and contrasting between the wealthiest and poorest 10% of households, looking at both time-steps. Firewood in particular is interesting to look at, given the assumption that all rural households routinely rely on it as the most readily available fuel source (Garekae et al. 2017), suggesting the relationship with poverty might be less tangible. The second set of analyses looked at how number of NR types harvested and proportional contribution to livelihood from NRs differ for wealthy and poor households. Measures of central tendency and t-tests for these two indices were extracted for the wealthiest and poorest 10% of households, and then Spearman's rho correlations were run for all households, testing the wealth index against total number of NR types harvested, proportional

contribution from NRs, and number of NR types sold. Extracting the wealthiest and poorest 10% of households resulted in small samples (n = 56 in 1995 and n = 48 in 2017). Although small, these sample sizes are above the threshold of the central limit theorem for assuming normal distribution, are independent, were collected randomly and were analyzed using Student's t-test, which is considered to be robust with even very small sample sizes (De Winter 2019, Kwak and Kim 2017).

The relationships between vulnerability vs. the two measures of NR reliance on the other, were tested using Spearman's rho correlations. Finally, given the observed changes in the sale of NRs, Spearman's rho correlations were run to assess the relationship between income from NRs, and proportional contribution to livelihood from NRs. These tests were run for both time-steps to assess how the contribution of NRs to rural livelihoods may have changed with rural communities becoming more integrated into the cash economy. All tests were run with 95% confidence intervals.

Results

Firewood in Chobe is the main fuel source for cooking, heating water, and some lighting. The importance of this resource in 1995 is clear from the high proportion of all households harvesting it (Figure 4a). In 1995, all the wealthiest 10% of households surveyed collected firewood, with almost all the poorest 10% also doing so (Figure 4b). By 2017, however, some of the wealthiest households appear to have shifted to other fuel sources, while a greater proportion of poorest households still relied on firewood. No sale of firewood was recorded by any households in 1995, and in 2017 only one of the wealthiest households had begun selling (Figure 4c).

A similar trend is shown for thatching grass (Figure 4) – a key roofing material in the absence of manufactured products such as corrugated iron or tile (that, unlike thatch, do not need regular replacing), but with usage levels significantly different for rich and poor households. In 1995, all wealthiest households harvested thatching grass, compared to a smaller proportion of poorest households ($n = 56$, $t = 2.423$, $df = 27$, $p = 0.022$). In 2017, poorest households strongly outnumbered wealthiest households in terms of still harvesting thatching grass ($n = 48$, $t = -2.086$, $df = 45.70$, $p = 0.043$) – suggesting that wealthier households were more able to switch to alternatives (Figure 4b). Although the number of wealthiest households selling thatching grass was significantly greater than the number of poorest in 1995 ($n = 56$, $t = 3.286$, $df = 27$, $p = 0.003$), the increased participation of poorest households in selling thatch by 2017 was not significant (Figure 4c).

The numbers of both wealthiest and poorest households engaged in fishing was low at both time-steps (Figure 4b). The trends for harvesting of edible and medicinal plants mirror that for firewood, but with significantly more of the wealthiest than poorest households engaged in plant harvesting in 1995 ($n = 56$, $t = 2.162$, $df = 48.9$, $p = 0.036$), but in 2017 the number of wealthiest households harvesting had decreased while the number of poorest households harvesting had increased so that the difference was no longer significant. At both time-steps, there were no strong differences between wealthy and poor households regarding sales of fish and wild plants (Figure 4c).

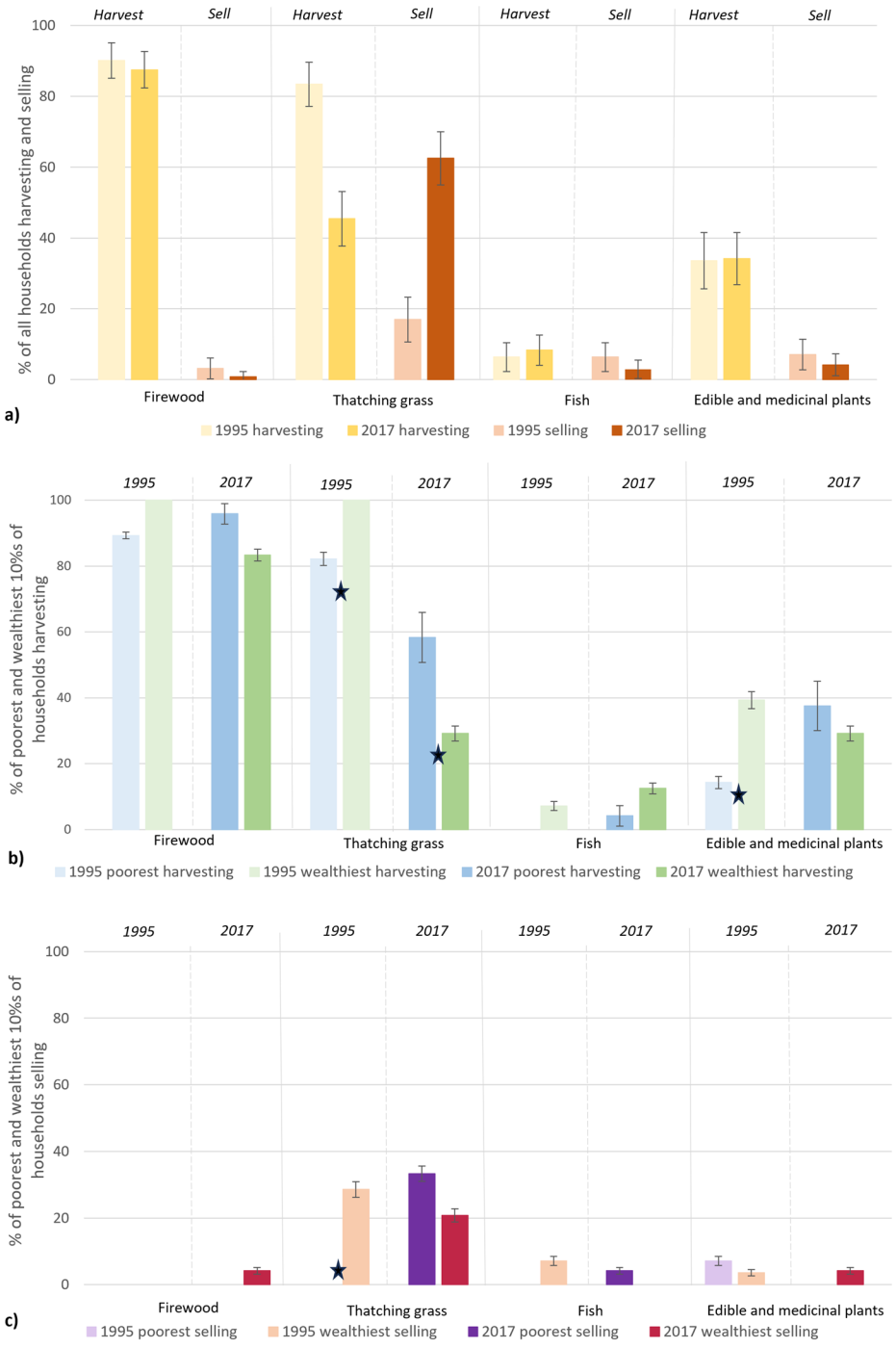

Figure 4. Percent differences in (a) harvesting and selling by all households, (b) harvesting by poorest 10% and wealthiest 10% of households, and (c) selling by poorest 10% and wealthiest 10% of households, of individual resource types at two time-steps, bar whiskers denoting 1 standard deviation.

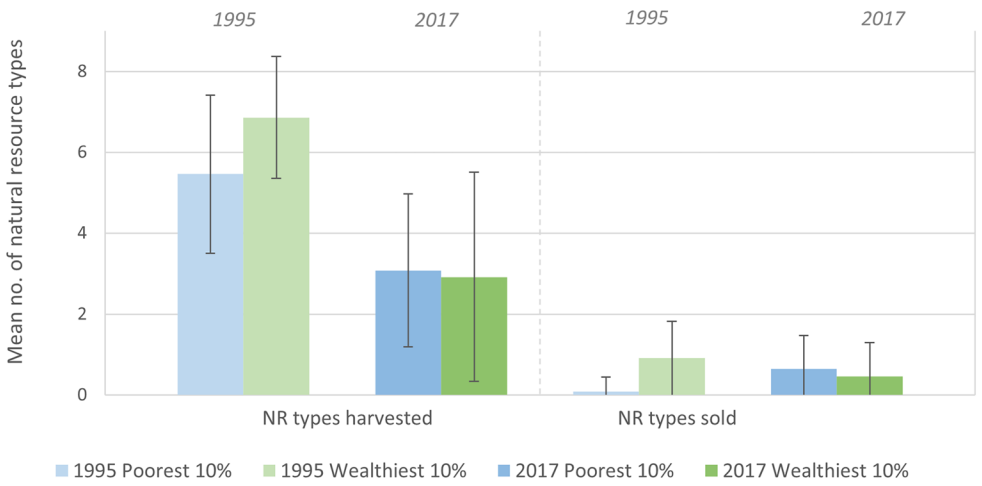

Figure 5. Differences between poorest 10% and wealthiest 10% of households in terms of number of resource types harvested and sold for 1995 and 2017, bar whiskers denoting 1 standard deviation.

In 1995, wealthiest households collected a wider range of NRs than poorest households (Figure 5) and wealth was significantly correlated with number of NRs harvested for all households ($n = 283$, $\rho = 0.147$, $p = 0.013$). By 2017, both wealthiest and poorest households collected fewer types of resources than two decades earlier; and although poor households now collected more than wealthy, it was only slightly so. There was a switch in the mean number of NRs sold between 1995 and 2017: for wealthiest households the mean number of resources sold almost halved, while for poorer households, there was an increase in the number sold. In 1995 the number sold by wealthiest households was higher than by poorest ($n = 283$, $\rho = 0.108$, $p = 0.077$). By 2017 the number sold by poorest households was higher than by wealthiest, though not significantly so (Figure 5).

Importantly, in 1995, despite collecting a smaller range of resources, poorer households relied on a significantly higher proportion of NRs for their total livelihood than did wealthier ($n = 283$, ρ=-0.468, $p < 0.001$; Figure 6). By 2017, although there was now very little difference in the number of resource types collected, the proportional contribution of NRs to total livelihood was still significantly higher for poorer households ($n = 240$, ρ=-0.380, $p < 0.001$), with a very small increase in the contribution of NRs to poorer households, and a marked decrease for wealthier households (Figure 6).

Vulnerability is significantly correlated with both total number of resource types harvested and proportional contribution from NRs at both time steps – but very differently for the two measures. Total number of resource types harvested is negatively correlated with vulnerability in both 1995 ($n = 283$, ρ=-0.452; $p < 0.001$) and 2017 ($n = 240$, ρ=-0.464; $p < 0.001$). Proportional contribution from NRs was positively correlated with vulnerability in 1995 ($n = 283$, $\rho = 0.205$; $p < 0.001$) but unexpectedly negatively correlated in 2017 ($n = 240$, ρ=-0.179; $p = 0.006$).

At both time-steps, as expected, poorer households had a higher proportional contribution from NRs and had higher vulnerability than did wealthier households (Figure 7). However, while poorer households harvested a smaller number of resource types

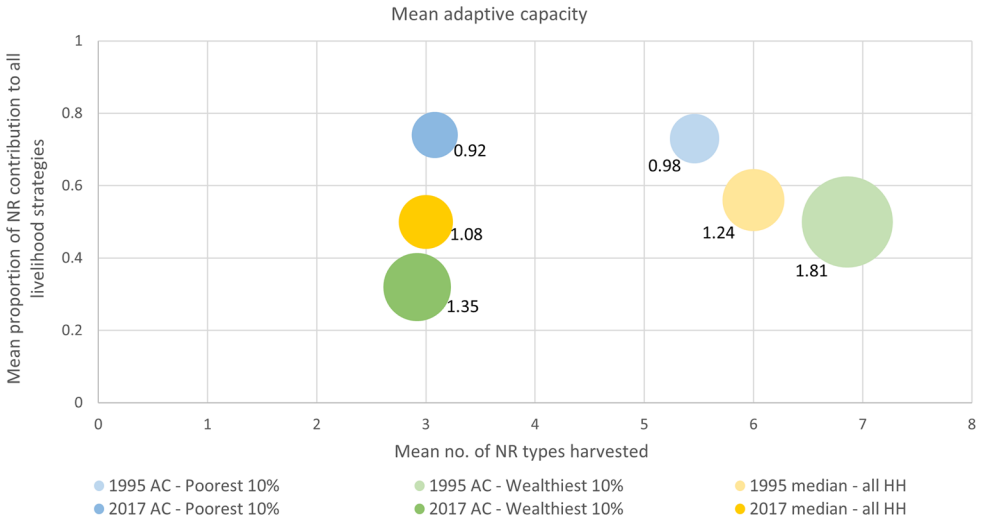

Figure 6. Differences between poorest 10% and wealthiest 10% of households in terms of proportional reliance on natural resources and number of resource types harvested for 1995 and 2017. Bubble size indicates wealth. Full sample medians for both time-steps displayed for context.

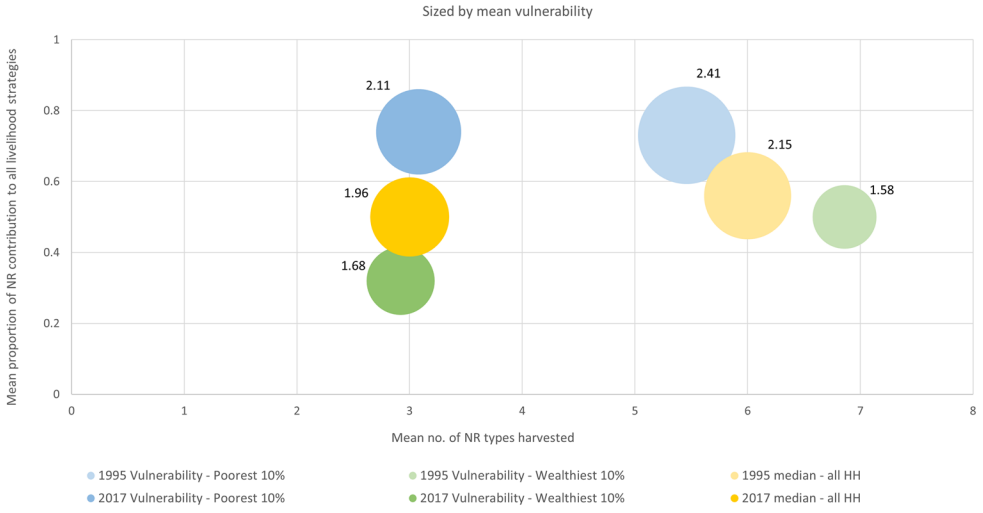

Figure 7. Relationship between vulnerability, number of natural resources harvested and proportional reliance on natural resources - contrasting poorest 10% and wealthiest 10 % of households in 1995 and 2017.Bubble size indicates vulnerability. Full sample medians for both time-steps displayed for context.

than wealthier households in 1995, by 2017 the mean number of types collected by wealthier households had dropped far more than for poorer households. While the vulnerability of poorer households decreased between 1995 and 2017, the proportional contribution of NRs to their livelihood did not. Between 1995 and 2017, the vulnerability of wealthier households increased as the proportional contribution from NRs

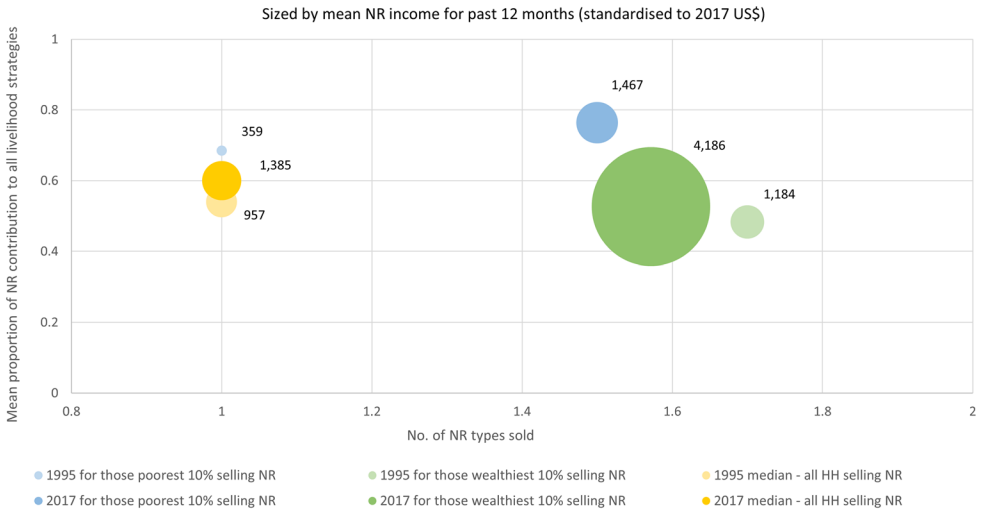

Figure 8. Relationship between income from natural resources, number of natural resources harvested and proportional reliance on natural resources - contrasting poorest 10% and wealthiest 10 % of households in 1995 and 2017. Bubble size indicates income from natural resources. Medians for both time-steps displayed for context.

decreased. These changing relationships suggest that the role of NRs within livelihood strategies has shifted.

To assess whether increasing commercialization of NRs could be contributing to the switch in correlation direction between proportional contribution to livelihood from NRs and vulnerability between 1995 and 2017, we explored the relationship between proportional contribution from NRs, number of NR types sold, and income from NRs.

We note that in both years, most households did not sell NRs, with only 33.6% in 1995 and 30.8% in 2017 selling. For households selling, mean income (standardized to 2017 US$) from NRs more than doubled between 1995 and 2017 ($n = 169$, $t = 3.442$, $df = 77.8$, $p < 0.001$), providing evidence of increasing commercialization of NRs. However, sales were not evenly distributed across all households, particularly in 1995. In that year, wealthy households sold more types of NRs and made more money from such sales than poor households, but NRs contributed a smaller proportion of their total livelihood than for poor households (Figure 8). In 2017, poor households now sold a wider range of NRs than in 1995, though still slightly fewer than wealthy households, and they still earned less on average from these sales than did wealthy households, and still relied more strongly on NRs as a high proportion of their total livelihood (Figure 8).

Looking at all households, in 1995 those who sold NRs had a smaller proportion of their total livelihoods derived from NRs ($n = 283$, $t = -0.455$, $df = 263.1$ $p < 0.001$), whereas in 2017, those who sold NRs had a significantly larger proportion ($n = 240$, $t = 6.566$, $df = 192.2$; $p < 0.001$). The sale of NRs switched from being negatively correlated with proportional contribution from NRs in 1995, to positively correlated in 2017.

Discussion

While our analyses largely supported our initial expectations regarding the difference between NRs harvested on the one hand, and proportional contribution of NRs to total livelihood on the other, there are some unexpected results that suggest that the modality of resource use has changed over time, from being purely subsistence harvest, to include commercial sale. We summarize our new understanding of the relationship between NR reliance, poverty, and vulnerability in terms of typologies of wealthy and poor households at the two time-steps in Figure 9. We discuss these changes in detail below.

The high reliance on NRs in 1995 for both wealthy and poor households can be ascribed to Chobe Enclave's then large degree of remoteness, when linkages to other places for cash-based livelihoods or to acquire manufactured materials (e.g., roofing, bricks) was limited. As expected, at that time wealthier households collected more NR types than poorer households. This is likely due to greater access to physical assets (tools and transport) and human resources (labor) (Cinner et al. 2006; Mertz et al. 2009). A shift to overall lower reliance on the NR base should be expected over time as connectivity increases, with the assumption that this would increase access to jobs and markets (Castaing Gachassin et al. 2015; Nakamura et al. 2020). Indeed, by 2017, we observed a reduction in the average number of NR types collected by both poor and wealthy households, though it should be noted that the reduction over time was greater for wealthier households, suggesting that they were better placed to shift from subsistence activities into the cash economy.

As households enter the cash economy and begin to rely more on cash-based livelihood strategies, they may harvest fewer NRs (Carter and Barrett 2007; Pender et al.

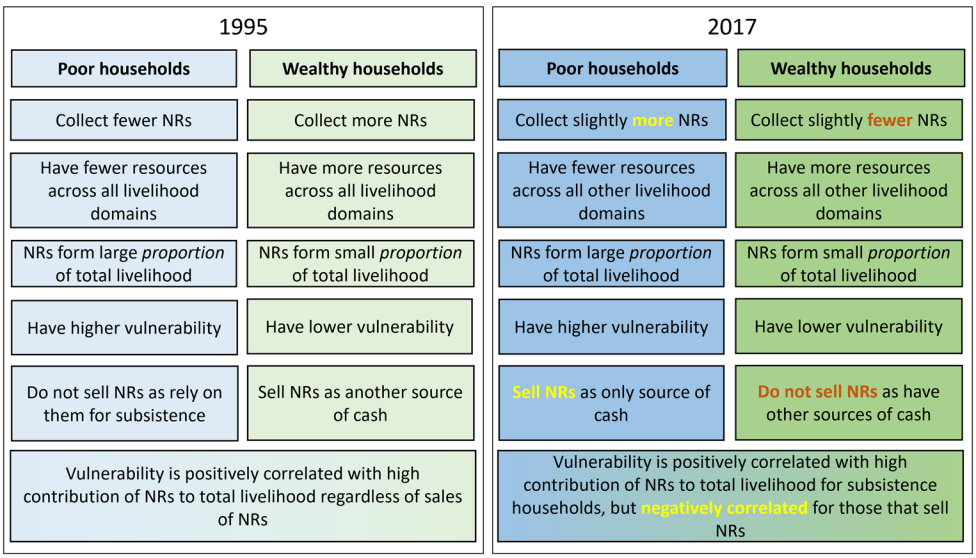

Figure 9. Summary typologies of changes in natural resource reliance, poverty and vulnerability over the past two decades, with yellow text highlighting increased usage or negative correlations in 2017 relative to 1995, and red text highlighting decreases in usage relative to 1995.

2003). However, we had expected that wealthier households would still be more involved in selling than poorer households (Sikor and Lund 2009), but this was not the case in our study. Indeed, the sale of NRs mirrors the pattern of harvesting NRs. In 1995, wealthier households not only harvested more resource types, but also sold more resource types, than did poorer households. But by 2017, the wealthiest households sold much fewer resource types, while the poorest households sold more. In 1995 wealthier households sold NRs as one of several cash economy activities, while in 2017, poorer households tended to have NR sales as the only, or main, source of cash income. It seems likely that selling NRs is a less reliable or consistent source of income, that was dropped by wealthier households who were able to engage in more secure forms of income such as wage employment, while poorer households increased their reliance on NRs through turning to selling as their only option (or one of very few) to access cash. The dependence of poorer households on NRs as a source of cash highlights their vulnerability, because environmental and climate variability and shocks make the availability of NRs unpredictable (Salerno et al. 2020; Vincent 2004), even as commercialization of NRs may be seen as an important adaptation (Ekblom 2012; Masunungure and Shackleton 2018).

In other contexts, the emergence of localized markets (Paudel Khatiwada et al. 2017) and globalization (Meyfroidt et al. 2010; Richards 2015) have seen wealthier households engaging more in the sale of NRs, rather than simply harvesting them for subsistence use. However, our data suggest a more nuanced situation with regard to changes in the sale of NRs. While wealthier households did indeed harvest fewer NR types, they did not do so because NRs were no longer a source of cash. Indeed, there was almost no change in the percent of all households selling NRs – the change was with regard to which households were now selling. These findings underscore the fact that the relationship between wealth and NR use in African savannas is complex and dynamic, and it is critically important to consider all aspects of NR use and reliance when evaluating vulnerability.

Vulnerability, as framed in terms of the assets, resources and capabilities, captured across the five livelihood domains, is known to vary strongly among rural households particularly where there is high inequality (Jurjonas et al. 2020). Typically, vulnerability is strongly correlated with poverty, and it is often assumed that the role of financial and physical assets in buffering both those characteristics may drown out the importance and contribution of other factors such as power relations (Natarajan et al. 2022). Less vulnerable households are able to diversify their livelihood strategies precisely because of the greater resources they may have access to under all livelihood domains, and livelihood diversity provides a buffer to climate and environmental shocks (De Sherbinin et al. 2008; Motsholapheko et al. 2012; Musumba et al. 2022). The challenge for the poor rural households in Chobe Enclave is twofold: they lack a wider range of livelihood strategies, and the options available to them - NRs - are a precarious foundation as availability is strongly dependent on the right environmental and climatic conditions. At first impression, therefore, collecting a diverse range of NRs (high number of resource types) may appear to be an important way to reduce vulnerability. However, as with wealth, our study suggests the relationship is more complex.

The total number of resource types collected was negatively associated with vulnerability in both 1995 and 2017. However, there was an unexpected switch for

proportional contribution from NRs: as expected, proportional contribution was positively associated with vulnerability in 1995, but two decades later, unexpectedly, negatively associated. This switch may be due to increasing commercial harvesting of NRs by rural households. Our initial expectation, that over time the relationship between NR use and vulnerability would weaken due to increased integration into the cash economy (Ellis 2000; Chhatre and Agrawal 2009), was based on an assumption that NR use would remain for the most part a subsistence activity, with very little selling of NRs. The data have shown this assumption to be incorrect. In 1995, only a few, wealthier households sold NRs. In 2017, the correlation between wealth and selling resources had fallen away, but the average number of NR types sold by the poorest households had increased substantially. This suggests that a commercially based reliance on NRs may indicate a diversification of livelihood options that decreases household vulnerability. In 1995, a household's vulnerability was related less to how much it relied on NRs, and more to whether it had other livelihood strategies as well or not. By 2017, it appears the relationship between vulnerability and NRs was based on whether a household relied on NRs for commercial or subsistence use. That is, subsistence reliance on NRs, or direct consumption of NRs as a proportion of total livelihood is still positively correlated with vulnerability. Proportional contribution to livelihood from subsistence use of resources still serves as an indicator not only of a household's poverty, but also to its vulnerability to external shocks such as climate change. This is not to say that reliance on NRs is itself a poverty trap – indeed, our findings are in line with other studies suggesting that trade in NRs may be a useful livelihood strategy not only for coping in the face of stress and shocks, but also as an important option in livelihood diversification (Shackleton et al. 2024). We summarize the shift in the relationship between NR use and vulnerability to encompass the role of commercialization in Figure 10.

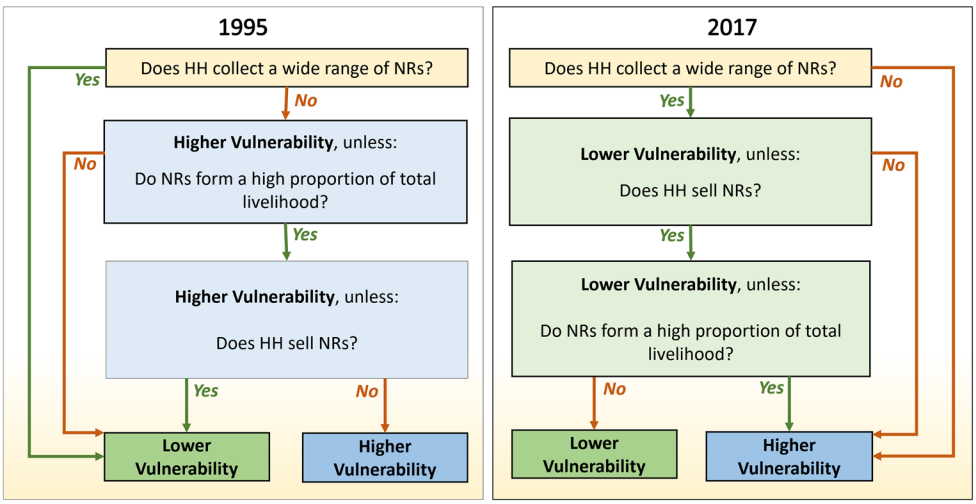

Figure 10. Changes in relationship between natural resource use and vulnerability over past two decades, representing conditions before and after broader community integration into cash economy.

Conclusion

Our data confirm that while poorer households may collect fewer NRs than do wealthier, they also have far fewer other livelihood strategies or sources of income. The high proportional contribution of NRs to poorer subsistence households' livelihood strategies is important in terms of understanding not only that rural households have different risks from climate and other environmental shocks, but also in terms of why this is so. Poor households are vulnerable not only because they rely on NRs, but because they have few alternatives (Barrett et al. 2001; Sunderlin et al. 2005). By shifting the emphasis of our analyses to proportional contribution to livelihood from NRs, we are better able to pinpoint a direct link between environmental shocks and such vulnerability (Gaughan et al. 2019; Mbiba et al. 2019). Different input variables may need to be specified for other study areas, but the shift of emphasis from total, to proportional, reliance on NRs is an important step in unpack rural household vulnerability, especially where access to financial capital is limited and/or skewed, and where reliance on common-pool NRs is high for the most vulnerable.

Policy documents on NRs management often treat communities as homogeneous entities where all households are equally vulnerable. Our findings have implications for how policy should better accommodate livelihood variability when defining access to NRs and its relation to rural poverty (Adhikari 2005). If poverty alleviation is a goal of NRs management, policies must set out secure access for those who most rely on NRs. If, for NR-reliant households, the pathway out of poverty is through sale of the resources they harvest (Shackleton et al. 2001, Shackleton et al. 2024), this creates an urgent need for simultaneously strengthening property rights (Ostrom 1990; Ribot et al. 2006), governance (Agrawal and Gibson 1999; Barratt and Allison 2014) and equity and justice (Thomas and Twyman 2005) in order to avoid a cycle of overexploitation, ecological degradation and increased poverty (Chhatre and Agrawal 2009; Meyfroidt et al. 2010). Just and equitable property rights would need to recognize that the same NRs may be more valuable to poorer, vulnerable households than to wealthier, resilient ones, and policies and area plans must ensure that sustainable management of commercial NRs harvesting is structured so that the practice both supports current households most in need and helps them to become more resilient, and remains available for future generations.

Longitudinal analyses of rural livelihoods are important for understanding changing relationships, but opportunities to do this are rare. Although the types of analyses possible in this study were limited by the structure of the older dataset, it is still possible to leverage such information for key insights into rural livelihood dynamics. While researchers should maximize their use of existing datasets, it is also important for those designing household surveys to accommodate the possibility of follow-up studies in the instrument structures.

Notes

1. https://data.worldbank.org/indicator/FP.CPI.TOTL?locations=BW.
2. Examples of how changes in proportion are measured against the whole are limited in the livelihood studies, but well-cited examples can be found in other arenas: meteorology (e.g., Duhan & Pandey 2013), medical trials (e.g., Collard et al. 2003), and cartography (e.g., McMaster 1986), among others.

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