The contested future of irrigation in African rural livelihoods – analysis from a water scarce catchment in South Africa

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Abstract

Agricultural improvement is seen as essential for economic growth, poverty reduction and food security in Africa. However, with new and priority demands for water agricultural allocations have come under closer scrutiny, particularly under water scarcity. In post-apartheid South Africa equitable water allocation has become an emblematic policy goal consistent with the imperative to create a fairer society. Catchment managers are now responsible for water allocation decisions across multiple and competing social, economic, environmental and political priorities. This analysis explores these challenges based on a study in the Luvuvhu catchment, Limpopo Province, which comprised (i) socio-economic evaluation of people’s livelihoods across 10 communities, (ii) hydrological modelling studies, and (iii) a detailed performance evaluation for one typical smallholder irrigation scheme. Findings from this study indicate that water allocation for smallholder irrigation provides expected income and food benefits for those with secure irrigation access. However, while increasing water allocation for smallholder irrigation may be argued to redress current inequitable distribution within the national irrigated agricultural sector, there is no convincing evidence to support allocating more water to smallholder irrigation schemes when viewed within the wider development challenges in the Luvuvhu catchment. It is argued that catchment managers should rather consider the hydrological and social benefits associated with improvements in dryland farming for increasing food security under water scarcity.

Keywords: Catchment management; Republic of South Africa; Rural development; Smallholder irrigation; Water allocation


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1. Introduction

Agricultural improvement is seen as essential for economic growth, poverty reduction and food security in Africa (IFAD, 2001; DFID, 2002; NEPAD, 2002; FAO, 2003), but what is the future role of irrigation? Proponents of irrigation point to the prospect of substantial improvements in agricultural productivity and intensity. They emphasize the contribution of irrigated agriculture to global food production arising from a five-fold increase in irrigated area in the last century from 50 to 250 million hectares. This increase contributed to improved yields, prices of staple foods reaching near historic lows and outputs which have matched the world’s average food requirement in the same period (Rosegrant et al., 2002). However, the contribution of irrigation to the success of the ‘green revolution’ in South Asia has not been evident in Africa, where production is dominated by dryland (rainfed) agriculture and yields remain low (around 1 tonne per hectare for staple grains) (Rockstrom et al., 2002).

In Africa, external funding for the development of irrigation infrastructure has declined in the past 20 years in response to criticism of irrigation policy for its inflated expectations and institutional failings. Moris (1987) argued that irrigation became the “privileged solution” to the problem of rural development such that it was seen as “self-evidently suited” to the problem of rural development and became an uncritical “blue-print approach”. Adams (1992) refers to the phenomenon as a pervasive culture of “irrigationism” amongst policy makers and donors. Other commentators focus on positive linkages between irrigation and poverty reduction such as increased cash generation, local multiplier effects, multiple-uses of irrigation (livestock, laundry), benefits to vulnerable groups such as female-headed households and forward linkages in the wider economy through job creation (van Koppen, 1998; Shah, 2000). Chambers (1988) cites several empirical studies which show irrigation directly raises employment for landless labourers. A World Bank evaluation (1997) identifies improved food security and increased income associated with its irrigation projects which are estimated to have benefited some 46 million farming families. Further, Hussain & Hanjra (2004) state that, global studies unfailingly document evidence of lower poverty rates when land is under irrigated production rather than rainfed production.

In the context of the renewed debate on the role of irrigation for both food security and poverty reduction, FAO (2003) argue for an increase in net irrigated area of 20% by 2030. In contrast, the International Food Policy Research Institute suggests this may not be necessary if the appropriate incentives to stimulate rainfed production are adopted (Rosegrant et al., 2002). SIWI (2001) also focuses on the potential of rainfed production gains with estimates of three-fold yield increases of staple grain crops (e.g. maize, sorghum, millet) with small-scale water harvesting interventions to off-set a predicted hidden annual food gap of 400 million tonnes in sub-Saharan Africa and south Asia1. Initial projections for 15–20% increase in irrigation by the International Water Management Institute (IWMI) have been repackaged into a more integrated environment and development platform encompassed by its Dialogue on Water, Food and the Environment (IWMI, 2000). For Africa, NEPAD (2002) identified agricultural intensification as a key part of its strategy for growth and proposed a 50% expansion of irrigation to 20 million hectares by 2015. Smith (2004) presents a review of the polarized views on the pros and cons of

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1 SIWI focus on land management innovations to more effectively use the primary water resource (rainfall) for small-scale food production rather than focus on the limited amount of rainfall partitioned as runoff, which is often less than 10% of rainfall in semi-arid tropical countries.
irrigation and notes that the importance of the distributional impact of irrigation interventions should be highlighted in relation to the limited availability of water resources and rural infrastructure in Africa.

In the Republic of South Africa (RSA), equitable water allocation has been an emblematic policy goal driven by the imperative to create a fairer society. This is influenced by at least two facts. First, the apartheid system of separate development and racial inequality resulted in 14 million black citizens being excluded from basic water services in 1994 (Perret, 2002). Second, average rainfall is low (less than 500 mm per year) and is highly variable often occurring in unpredictable cycles of droughts and floods. The latter fact has long been recognised and acted upon through extensive water resource development leaving few new opportunities for further water storage or cross-boundary transfers. As water resources are almost fully developed the need for trade-offs and transfers between water use sectors has been debated nationally and informed new water legislation. Water is defined as “an indivisible national asset” with priority allocations to basic human needs and ecological systems (RSA, 1998).

Given new and priority social and environmental water claims in an economy with high-value industrial water demands, water allocations to agriculture have come under closer scrutiny. As in most countries, agriculture takes the biggest share of available water resources (over 50%) but contributes a smaller proportion (5%) to Gross Domestic Product compared to some sub-Saharan African countries (up to 80%) (de Lange, 2004). Of the 16 million hectares of arable land less than 10% is irrigated but this contributes 25% of total output partly due to over 85% of irrigated land being planted with higher value and higher investment crops such as grapes, citrus or tobacco (Backeberg, 2003). Reflecting historical inequalities, the agricultural sector consists of a mainly white commercial sector of large modern farms and a smallholder sector of black emerging or subsistence farmers. The commercial sector consists of some 25,000 farmers who use 95% of irrigation water. The largest area under smallholder irrigation is found on many smallholder irrigation schemes in the former Homelands (or Bantustans) where an estimated 40,000 farmers tend plots of one to two hectares (Perret, 2002). These farmers largely produce for home consumption (de Lange, 2004). More equitable access to irrigation offers one way in which water legislation could contribute to poverty reduction within the political imperative to revise water legislation to favour previously disadvantaged communities. However, as Marna de Lange (2004) discusses, this poses a difficult but important question: “is it in the national interest to spend resources on such an embattled sector (smallholder irrigation), which will increase the use of a very scarce resource for relatively low value production?” 4.

In this context, this paper explores the case for smallholder irrigation through a socio-economic analysis of a smallholder scheme within a wider hydrological analysis of the Luvuvhu catchment. The Khumbe scheme is a relatively rare example of a smallholder irrigation scheme which has

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2 In a national rural survey, 93% households reported small-scale dryland farming for home consumption with maize as the dominant crop grown (92%) (StatsSA, 1999).

3 The recent history of smallholder irrigation schemes dates back to the 1955 Tomlinson Report and the inequality of land access for the majority black population following the 1913 and 1936 Land Acts. ‘Border development’ policy of the 1950s introduced many smallholder irrigation schemes as a politically-motivated response to improve livelihoods in overcrowded Homeland areas (Tomlinson, 1955; Yawitch, 1981; Perret, 2002). However, during the early 1990s subsidies were withdrawn precipitating the collapse of the majority of smallholder schemes (Crosby et al., 2000).

4 Food self-sufficiency is not a national policy goal and though smallholder irrigation would be consistent with stated policy if it contributed to household food security, the success of state social transfers has highlighted that household food security for disadvantaged groups (old, disabled) is not only influenced by the ability to grow food but also by the ability to buy food (Dreze & Sen, 1989).
functioned continuously since its construction in the 1950s. This is useful in comparing irrigation scheme farmers with land-based and non-land-based livelihoods in the wider catchment. The analysis attempts to better understand livelihood impacts of water allocation to a smallholder irrigation scheme within a catchment context and to consider the implications of water allocation to smallholder irrigation as a catchment management intervention for rural development under water scarcity. The paper follows with a description of research methods and the study area in Section 2, results are reported in Section 3, and wider implications are discussed in Section 4.

2. Research methods and study area

2.1. Research methods

The study has three methodological approaches. The first is socio-economic evaluation of people’s livelihoods based on household questionnaire data across 10 catchment communities (Figure 1). The second is a collection of irrigation performance criteria including crop yield (tonnes per hectare), crop productivity (US$ per m³ water) and indicators for the performance of the irrigation scheme (Molden et al., 1998). The third is hydrological modelling at the catchment-level with land use change evaluation (Jewitt & Schulze, 1999). The aim is to link the three approaches to provide a more integrated understanding of smallholder irrigation impacts on livelihoods and water allocation at the scheme and catchment scales.

Fig. 1. Luvuvhu catchment, Limpopo Province, South Africa.
Socio-economic findings are informed by an iterative sequence of quantitative and qualitative research. First, a baseline household survey (January 2002; \( n = 552 \)) was implemented in eight purposively selected communities across the Luvuvhu catchment. Second, participatory inquiry was conducted in Khumbe and other communities during several extended visits in 2002 and 2003, including focus group discussions, seasonal calendars, institutional mapping, farm transect walks and informant interviews. Third, two targeted household questionnaires were administered in October 2003. The first was a farm budget survey of Khumbe irrigation farmers (\( n = 40 \)) to capture detailed farm production data and the second explored water policy scenarios in two downstream Luvuvhu communities (Hope & Garrod, 2004). As the same socio-economic questions were asked in both questionnaires findings can be usefully compared. The farm budget survey had a purposive random sampling strategy in order to capture intra-scheme impacts of plot location, which is often a proxy for irrigation access or control and was identified as an important issue in the scoping participatory study. Net values of crop returns at Khumbe include labour and input estimates of land preparation, weeding, sowing, irrigation, traction, harvesting and processing. Labour day rates are set from local agricultural monthly wages of US$66 (R460) in 2003, which is lower than the rural minimum wage (US$93) but higher than informant reported rates of US$43 per month (Hope, 2004). Crop prices are local farm gate prices reported by farmer informants. Income data are reported with adult equivalent estimates. The third strand of analysis is informed by hydrological modelling of the catchment led by the University of KwaZulu-Natal. Results from the ACRU agro-hydrological model are presented in discussion of catchment-level water allocation decisions (Jewitt & Schulze, 1999; Hope et al., 2004; Jewitt & Garratt, 2004).

2.2. Study location

Khumbe community is located in the Luvuvhu catchment, Limpopo Province. Limpopo Province ranks as one of the three poorest of RSA’s nine provinces along with Kwa-Zulu Natal and Eastern Cape across a range of drinking water, fuel, sanitation, employment and education development indicators (StatsSA, 2003). Limpopo Province records the highest concentration of smallholder irrigation schemes by area (42%) and by number (50%) in RSA (Backeberg, 2003). Many of the 114 smallholder schemes in Limpopo Province are being rehabilitated (Perret, 2002; Stimie, 2003; Veldwisch, 2004) after their general collapse in the early 1990s following withdrawal of state subsidies and support (Crosby et al., 2000). Studies of operational smallholder schemes in Limpopo Province report evidence of water access inequalities (Veldwisch, 2004), household food security as a primary farming objective (van Averbeke & Perret, 2004), and larger irrigation land owners gaining a greater share of household annual income from non-farm sources (Veldwisch, 2004; Lahiff, 1997).

The Luvuvhu catchment measures 5,941 km² and forms part of the Luvuvhu/Letaba water management area, which is one of 19 areas identified nationally by the Department of Water Affairs and Forestry (DWAF). The catchment is a tributary to the larger Limpopo basin which drains into the Indian Ocean.

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5 Enumerators were all local Venda-speaking students who lived in the catchment.

6 Organisation for Economic Cooperation and Development’s (OECD) formula:

\[
\text{Adult Equivalent} = 1 + 0.7N_{\text{adults}} - 1 + 0.5N_{\text{children}}.
\]

Changing the equivalent scale coefficients determines relative economies of scale which attempt to approximate intra-household consumption.
Ocean in southern Mozambique. The catchment is sub-divided into 14 quaternary catchments (QC) for water resource management purposes (Table 1). Potential evaporation is estimated at 1,678 mm per year and mean annual precipitation is estimated at 608 mm per year with strongly skewed seasonal distribution typified by 80% of precipitation falling in the summer months from October to March (Figure 2). In addition to strong temporal variation, all these values show high spatial variation with higher rainfall and lower evaporation in the south western section of the catchment near the Soutpansberg mountain range and low rainfall and high evaporation in the north eastern area which includes the northern section of the Kruger National Park. Within the rainfall season, rainfall patterns are also highly variable. The importance of the spatial and temporal distribution of rainfall for growing dryland maize is illustrated by a study which predicts that 81% of the Luvuvhu catchment receives insufficient rainfall within the growing season to sustain a rainfed maize crop over a ten year simulation analysis (Spice, 2003). However, dryland agriculture remains an important livelihood activity and represents 10% of catchment land use compared to 50% rangeland, 30% conservation areas, 4% commercial forestry, 3% commercial irrigation and 3% urban (Hope et al., 2004).

The catchment population is 624,000 people, who live in 380 scattered communities. The main urban area is Thohoyandou (pop. 130,000) with most of the limited industry around its hub. Mean annual runoff (MAR) is estimated at 520 million m³ per year with an Ecological Reserve requirement estimated to be 105 m³ per year. Water use demands in the catchment are estimated at 97 million m³ for irrigation, 14 million m³ for urban and rural drinking water, 8 million m³ for commercial forestry and invasive alien vegetation, and one million m³ allocated to industrial supply, largely through a historical inter-basin transfer of water to Louis Trichardt. DWAF (2004) estimate that 37 million m³ of water per year are available to support further development. However, it has been estimated that combined water abstractions use all available water resources, particularly in the critical low flows period of August through November (Jewitt & Garratt, 2004). Consequently any benefit from the available water is unlikely to be realised without construction of additional storage. Current storage capacity in the catchment is estimated at 40 million m³ (8% of MAR), mainly in four large dams: Albasini, Vondo, Tshakuma and Nandoni.

Khumbe is located 40 km south west of Thohoyandou on the main Louis Trichardt - Punda Maria sealed road which joins the main trunk road linking the northern RSA border with Zimbabwe and Pretoria (circa. 500 km). Khumbe’s population is estimated at 2,000 inhabitants with 126 households having access to an irrigation plot. Khumbe enjoys a relatively high mean annual rainfall of 961 mm with 85% falling in the summer months. Frost rarely occurs, which provides an agricultural advantage compared to many areas of the country. The irrigation scheme was built in 1953 with a command area of 137 hectares. The irrigation scheme led to population growth and development of the Khumbe community. Land tenure operates on a long-enduring system of patriarchal hereditary rights. A land tax of 12 Rands (US$2) per plot per year is paid to the local municipality, who provide irrigation maintenance services on a reportedly ‘erratic’ basis. Land rights are hereditary and no active land market exists. Land may be reallocated by the Farmers Committee (FC) if the land is deemed to have been

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7 The Reserve consists of priority water allocations for Basic Human Needs and Ecological requirements (RSA, 1998). While a free Free Basic Water Provision household allocation of 6,000 litres per month has been set nationally, the Ecological Reserve varies by location and environmental conditions.

8 Key informants in the community report that subsistence farmers on the neighbouring slopes of the Soutpansberg mountain range settled the area upon successful applications for an irrigation plot.

abandoned for a number of planting seasons or if the current owner wishes to reallocate their plot amongst family members. In this way, approximately 10 plots have been divided alongside half a dozen farmers gaining access to larger plot areas. Some farmers have appropriated ‘unused’ land if their claim is approved by the FC. Land is inherited by family members with no recorded land purchases during the last fifty years. The FC is elected every three years and is currently representative of head, tail, male and female farmers.\(^{10}\)

The Khumbe scheme was purposively located to divert streamflow from the Dzondo River, which is a tributary to the perennial Luvuvhu River. A gravity-fed irrigation system is supplied by a hierarchical system of canals with three reservoirs. DWAF award an annual water resource allocation of one

\[\text{Table 1. Rainfall, communities and predicted rainfed maize yields.} \]

<table>
<thead>
<tr>
<th>Quaternary catchment</th>
<th>Area (hectares)</th>
<th>Mean annual rainfall (mm)</th>
<th>Rainfed maize yields (tonnes per hectare)*</th>
<th>Sampled community</th>
</tr>
</thead>
<tbody>
<tr>
<td>A91A</td>
<td>23266</td>
<td>381</td>
<td>0.88</td>
<td>n/a</td>
</tr>
<tr>
<td>A91B</td>
<td>27517</td>
<td>622</td>
<td>0.15</td>
<td>n/a</td>
</tr>
<tr>
<td>A91C</td>
<td>24976</td>
<td>879</td>
<td>0.79</td>
<td>n/a</td>
</tr>
<tr>
<td>A91D</td>
<td>13253</td>
<td>1260</td>
<td>1.81</td>
<td>n/a</td>
</tr>
<tr>
<td>A91E</td>
<td>22331</td>
<td>961</td>
<td>0.99</td>
<td>Khumbe, zwerani</td>
</tr>
<tr>
<td>A91F</td>
<td>58025</td>
<td>618</td>
<td>0.04</td>
<td>Ha-Matsika</td>
</tr>
<tr>
<td>A91G</td>
<td>40613</td>
<td>883</td>
<td>0.29</td>
<td>Vondo, Makonde</td>
</tr>
<tr>
<td>A91H</td>
<td>45010</td>
<td>662</td>
<td>0.0</td>
<td>Lukalo</td>
</tr>
<tr>
<td>A91J</td>
<td>57000</td>
<td>461</td>
<td>0.0</td>
<td>n/a</td>
</tr>
<tr>
<td>A91K</td>
<td>66927</td>
<td>381</td>
<td>0.0</td>
<td>n/a</td>
</tr>
<tr>
<td>A92A</td>
<td>32920</td>
<td>859</td>
<td>0.53</td>
<td>Rambuda, Gogogo</td>
</tr>
<tr>
<td>A92B</td>
<td>56534</td>
<td>654</td>
<td>0.02</td>
<td>Mangaya</td>
</tr>
<tr>
<td>A92C</td>
<td>113999</td>
<td>438</td>
<td>0.0</td>
<td>n/a</td>
</tr>
<tr>
<td>A92D</td>
<td>80483</td>
<td>307</td>
<td>0.0</td>
<td>Mutele A</td>
</tr>
</tbody>
</table>

*Predictions based on FAO MAYSIM model for data for the period 1952–1961 (Spice, 2003)

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\[\text{Fig. 2. Annual rainfall distribution in the A91E quaternary catchment (1950–2000).} \]

10 Head and tail farmers are distinguished in relation to their location in the irrigation scheme; head farmers benefit from more secure water access due to proximity to water inflows.
million m$^3$ water to the community from the river diversion. This allocation has always been free. Irrigation distribution to the farmers is on a self-enforced rotation basis. A scheme layout, based on the original engineering design, is the framework for plot-level water distribution but equitable allocation is often contested, particularly by the farmers located in the tail section. DWAF employs one community member to monitor distribution of water to the farmers. The FC is the principal institution to hear and rule on farmer complaints with the Tribal Authority having no reported influence or authority. Head farmers state there is insufficient irrigation for all the plots, particularly in the dry season. Physical violence between farmers has been reported but complaints to the local municipality have never occurred, which is the secondary institutional recourse for disputes.

3. Results

3.1. Socio-economic

3.1.1. Khumbe in the catchment context. The 2002 questionnaire allows comparison of socio-economic characteristics of Khumbe irrigation farmers with a) other Khumbe households without an irrigation plot, b) non-Khumbe catchment households who farm dryland plots of similar size to irrigation plots, and c) non-Khumbe catchment households who do not have dryland access (Table 2).

Khumbe households have less members and older adults than the dryland or landless groups. Within Khumbe, non-irrigation households have the lowest number of members with an average of just over two adults and two children, which is lower than the catchment average of roughly three adults and three children per household. Irrigation households tend to be older which is reflected in the highest level of state pension transfer (US$444 per year). Just over one in two dryland households fall in the higher rainfall zone compared to one in five landless households.

The condition of the main dwelling was evaluated for each respondent and here a composite category of ‘poor’ includes a dwelling made of mud or thatch or in a temporary or dilapidated state; this compares to a western-style brick dwelling in good condition. One in ten of irrigation owners’ main dwelling is classified as ‘poor’. Non-irrigation Khumbe dwellings are in a slightly worse state (21% poor) with dryland and landless dwellings close to the catchment average of one in three of main dwellings being in a poor state. Irrigation households record a higher level of access to a domestic water tap in the home (64%) compared to their Khumbe neighbours (29%), dryland owners (30%) or landless households (23%). Access to drinking water within 200 metres of the home is achieved by more than one in two households in the landless group (55%). The other household groups cluster in the range of 31–46% within 200 metres. Khumbe community reports almost universal access to pit latrines compared to two in three households in the dryland or landless groups. Khumbe has a lower level of electricity access.
Table 2. Household characteristics by land and irrigation access in the catchment context.

<table>
<thead>
<tr>
<th></th>
<th>Khumbe community</th>
<th>Luvuvhu catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigation land</td>
<td>No irrigation land</td>
</tr>
<tr>
<td></td>
<td>( (n = 11) )</td>
<td>( (n = 68) )</td>
</tr>
<tr>
<td>Household members</td>
<td>5.18 (0.38)</td>
<td>4.21 (0.20)</td>
</tr>
<tr>
<td>Adults (over 16 years)</td>
<td>2.55 (0.37)</td>
<td>2.12 (0.13)</td>
</tr>
<tr>
<td>Adult average age</td>
<td>49.07 (5.53)</td>
<td>40.14 (1.43)</td>
</tr>
<tr>
<td>Mean household income</td>
<td>2062.86 (580.19)</td>
<td>3146.70 (481.43)</td>
</tr>
<tr>
<td>(US$ per year)</td>
<td>1611.43</td>
<td>1517.14</td>
</tr>
<tr>
<td>Household pension income (US$ per year)</td>
<td>444.16 (153.86)</td>
<td>287.39 (64.93)</td>
</tr>
<tr>
<td>Dryland (hectares)</td>
<td>n/a‡</td>
<td>1.55§ (0.47)</td>
</tr>
<tr>
<td>Dryland income (US$ per hectare)</td>
<td>n/a</td>
<td>21.43§ (7.14)</td>
</tr>
<tr>
<td>Proportional household food use of dryland harvest</td>
<td>n/a</td>
<td>0.89 (0.06)</td>
</tr>
<tr>
<td>Irrigation land (hectares)</td>
<td>1.54 (0.39)</td>
<td>0</td>
</tr>
<tr>
<td>Irrigation income (US$ per hectare)</td>
<td>141.78** (51.80)</td>
<td>n/a</td>
</tr>
<tr>
<td>Proportional household food use of irrigation harvest</td>
<td>0.60 (0.09)</td>
<td>n/a</td>
</tr>
<tr>
<td>% of households in &gt; 700 mm per year rainfall zone</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Dwelling in poor condition††</td>
<td>9%</td>
<td>21%</td>
</tr>
<tr>
<td>Drinking water tap in home</td>
<td>0.64 (0.15)</td>
<td>0.29 (0.06)</td>
</tr>
<tr>
<td>Greater than 200 metres to drinking water supply</td>
<td>54%</td>
<td>69%</td>
</tr>
<tr>
<td>Pit latrine sanitation</td>
<td>1.00</td>
<td>0.93 (0.03)</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.45 (0.16)</td>
<td>0.18 (0.05)</td>
</tr>
<tr>
<td>Cattle</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Mean (standard error). Data drawn from the 2002 Luvuvhu catchment questionnaire \( (n = 552) \).

* Households reporting dryland in the range 0.20–4.00 hectares to be equivalent to the range of irrigation land.
† Median income is reported to provide an alternative estimate to mean estimates from a skewed income distribution.
‡ One household reports a one hectare field.
§ Eleven households report dryland in this sample (16%).
|| These estimates are for only 2 households report dryland income, 97% of the sample report no income.
†† Main dwelling made of mud or thatch or in a temporary/dilapidated condition.
than the catchment average of two in three households. Within Khumbe, households with irrigation plots are twice as likely to have electricity access. Average cattle ownership is less than two head per household and concentrated in the dryland and landless groups with no cattle reported in Khumbe\textsuperscript{13}.

Dryland access is slightly higher for Khumbe non-irrigation households (1.55 hectares) than the dryland group (1.29 hectares). The majority of these households do not sell any of their crops, 97% and 93% respectively, which is consistent with national rural data (\textit{StatsSA, 1999}). Of the few households that do sell some of their dryland produce, modest returns are reported (US$21–63 per hectare). Households tend to consume the summer crop (usually, maize) with a high proportional estimate of crop allocation to household consumption, 89% and 95% of respective yields. Irrigation land ownership is higher (1.54 hectares) than dryland with a higher estimated income per hectare (US$142). This corresponds with a lower crop allocation to household food consumption (60%).

Average annual income data indicate that non-irrigation Khumbe households have the highest mean annual income (US$3,147), followed by dryland (US$2,644), landless (US$2,409) and then Khumbe irrigation owners (US$2,063). Given the common problem of skewed income distribution, a median household income measure is reported, which results in irrigation households with the highest income (US$1,611) followed by non-irrigation households in Khumbe (US$1,517), dryland (US$1,371) and landless (US$1,029). Due to the influence of state pension transfers this income is separately reported\textsuperscript{14}. As expected, older irrigation households record the highest level of state transfers (US$444 per year) followed by dryland (US$438), landless (US$307) and Khumbe non-irrigation (US$287). Median adult equivalent income is considered a less-biased indication of household welfare and may be compared with common global income poverty thresholds of US$1 or US$2 per day per person. Irrigation households record the highest median adult equivalent income per year (US$605) followed by Khumbe non-irrigation (US$540), dryland (US$390) and landless (US$376). All households fall between the US$1 and US$2 thresholds. Irrigation households are close to the US$2 threshold while dryland and landless groups are located just above the US$1 line. The catchment median adult equivalent estimate is US$407 per year.

3.1.2. Social impacts by irrigation access. Disaggregation of the 2003 Khumbe farm budget survey illustrates different social impacts subject to irrigation access (\textit{Table 3}). Head plots are owned almost exclusively by male-headed households in comparison to one in three tail plots owned by female-headed households. Household composition between plot locations is broadly similar with over six people per household, including around four adults. Farmers in head plots report that their households have been actively farming their irrigated land for over 41 years compared to under 25 years for tail plot owners. Plot location influences plot size with head plots smaller (1.04 hectares) than tail plots (1.37). However, plot size does not influence gross annual farm returns as much as plot location. Head plots are estimated to generate US$2,047 per year compared to US$543 per year for a tail plot.

\textsuperscript{13} Cattle ownership is generally concentrated with a few, larger owners in the semi-arid north east of the catchment. Its importance as a social and livelihood activity in the catchment has diminished partly due to a combination of droughts, disease, theft and the withdrawal of government veterinary support and monitoring.

\textsuperscript{14} Qualification for the US$100 per month (2003) old age grant is 60 years for women and 65 years for men. Qualification depends on appropriate paperwork which can be problematic as apartheid employment, education and freedom of movement (Pass Laws) contributed to false or inaccurate records which now prejudice qualification for some people. Similar problems apply to accessing other state transfers such as the Child Support Grant (children under 7 years) (\textit{Hope, 2004}).
Table 3. Socio-economic impacts by irrigation access and catchment location.

<table>
<thead>
<tr>
<th></th>
<th>Khumbe Head (n = 20)</th>
<th>Khumbe Tail (n = 20)</th>
<th>Ha-Matsika (n = 40)</th>
<th>Lukalo (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female-headed households</td>
<td>10%</td>
<td>35%</td>
<td>30%</td>
<td>33%</td>
</tr>
<tr>
<td>Household members</td>
<td>6.65 (0.64)</td>
<td>6.80 (0.45)</td>
<td>6.45 (0.39)</td>
<td>5.63 (0.43)</td>
</tr>
<tr>
<td>Adult members</td>
<td>4.45 (0.32)</td>
<td>3.70 (0.26)</td>
<td>3.63 (0.30)</td>
<td>3.33 (0.24)</td>
</tr>
<tr>
<td>Years farming</td>
<td>41.45 (1.69)</td>
<td>24.40 (2.48)</td>
<td>n/k</td>
<td>n/k</td>
</tr>
<tr>
<td>Irrigated land (hectares)</td>
<td>1.04 (0.05)</td>
<td>1.37 (0.12)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Dryland (hectares)</td>
<td>n/a</td>
<td>n/a</td>
<td>1.47 (0.28)</td>
<td>0.48 (0.17)</td>
</tr>
<tr>
<td>Gross household income</td>
<td>4678.65 (434.39)</td>
<td>2720.49 (326.18)</td>
<td>776.21 (177.36)</td>
<td>2041.29 (380.29)</td>
</tr>
<tr>
<td>(US$ per year)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Median household income</td>
<td>4660.71</td>
<td>2647.54</td>
<td>0*</td>
<td>1514.29</td>
</tr>
<tr>
<td>(US$ per year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median adult equivalent income</td>
<td>1066.40</td>
<td>642.59</td>
<td>0*</td>
<td>501.23</td>
</tr>
<tr>
<td>(US$ per year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Income by sector (US$ per year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross farm income</td>
<td>2047.39 (155.40)</td>
<td>542.52 (32.68)</td>
<td>n/k</td>
<td>n/k</td>
</tr>
<tr>
<td>Non-farm income</td>
<td>1851.26 (369.05)</td>
<td>677.97 (165.23)</td>
<td>236.21 (130.25)</td>
<td>1831.29 (369.88)</td>
</tr>
<tr>
<td>Old age state transfer</td>
<td>780.00 (218.08)</td>
<td>1500.00 (211.01)</td>
<td>540.00 (128.54)</td>
<td>570.00 (121.43)</td>
</tr>
</tbody>
</table>

Mean (standard error); ^data drawn from two questionnaires administered simultaneously in October 2003 with identical socio-economic sections but differing farm budget or choice experiment components (Hope, 2004). n/a – not applicable; n/k – not known; *52.5% of Ha-Matsika households record no income.
Non-farm income by location indicates households at the head of the scheme generate US$1,851 per year compared to US$678 per year at the tail. In contrast, tail households receive higher levels of state pension transfers (US$1,500) compared to head households (US$750). This is reflected in head farmer households’ annual income of US$4,679 compared to US$2,720 for tail farmer households. Median annual household annual income values are broadly in line with these averages. Median adult equivalent income is estimated at US$1,066 per head farmer household member and US$643 per tail farmer household member.

These income estimates correspond reasonably well to the 2002 estimates from the smaller irrigation sample size (n = 11). Differences occur in disaggregation by location, estimating a gross income value from irrigated production (not directly captured in the 2002 survey) and the level of state pension transfers. The gross household income estimate (non-farm plus pension) for irrigation owners of US$2,063 per year in the 2002 survey is similar to the gross household income estimates (non-farm income and pension) for tail farmer households (US$2,178) in 2003 but lower than the estimate for head farmer households (US$2,631). However, if pension income is excluded from the 2003 estimates, head farmer gross household income estimate (US$1,851) shows a reasonable match to the 2002 irrigation owner income estimate (US$1,619). Assuming a cautious level of confidence in comparing across the irrigation income data, it may be inferred that including gross farm returns in household income analysis results in an additional US$400 per year per adult equivalent unit for head farmers and an extra US$40 per adult equivalent unit for tail farmers. This interpretation is only indicative as farmers are unwilling or unable to sell all their produce at local market prices used in estimating gross returns.

3.1.3. Irrigation as a driver of income diversification? Socio-economic findings from the 2003 Khumbe data are compared with Ha-Matsika and Lukalo communities in the drier lower reaches of the Luvuvhu River in an attempt to understand the role of water (irrigation and rainfall) and community location on livelihood outcomes (Table 4). Household composition of these two downstream communities is similar to tail Khumbe farmers with a third of the households female-headed comprising of approximately six people. Ha-Matsika households report dryland ownership (1.47 hectares) similar to tail Khumbe farmers and roughly three times more land than in Lukalo (0.48). Access to land appears to have little influence on household income as Ha-Matsika households report a gross annual estimate of US$776 compared to US$2,041 for Lukalo households. While farm income was not adequately captured, pension income is found to be equivalent for both communities (US$540 and US$570 per year, respectively). There is a large inter-community income-generation difference for non-farm income with Lukalo households reporting US$1,831 per year, a figure comparable with head irrigation plot owners at Khumbe. This contributes to Lukalo residents recording a median adult equivalent income of US$501 per year; a figure only slightly lower than the Khumbe non-irrigators and 25% higher than the catchment median in 2002. In contrast, over 50% of Ha-Matsika households record no income, which results in no median income estimate.

These findings suggest that household income security is influenced more by access to non-farm income and less by land access. However, where land access is linked to secure water access the opportunity for income-generation appears high. It is uncertain whether irrigation access is the key

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15 A one sample t-test indicates no significant statistical difference (t = -1.61; df = 39; p > 0.05) when a combined head and tail sample of average non-farm income from the 2003 sample (US$1,265) is tested against the 2002 average non-farm income estimate for irrigation plot owners (US$1,619).
driver for diversification out of farming and into higher value non-farm wage employment at Khumbe or, whether non-farm wage households have social and political influence to secure more desired irrigation plots. Evidence of the latter is reported at the Thabina scheme in Limpopo Province (Veldwisch, 2004). At best irrigation access at Khumbe has contributed to diversification into non-farm employment for head farmers alone as tail farmers remain relatively income poor in the wider community context and depend on state transfers for over half of household annual income.

3.2. Crop choice, yield and returns

3.2.1. Crop choice. Farmer crop selection in Khumbe by season is summarised in Figure 3. In the wet (summer) season, maize is the only universal crop grown. In the dry (winter) season, tomatoes are the dominant crop. The five other most common crops are sweet potato, cabbage, groundnuts, pumpkin and onion. None of these crops are high margin crops (such as chillies or sweet peppers) but are characterised by a high perishable threshold reflecting crop choices common to dryland, subsistence production across the catchment. This is consistent with a low risk, expenditure-saving rather than income-generating
livelihood strategy. This is illustrated by a low proportion of harvest sold in the wet season (29–54%) compared to the dry season (32–72%).

3.2.2. Crop yield. Area planted by specific crops was difficult to capture adequately restricting economic analysis to gross or net income per hectare. However, the universal planting of maize in the wet season by all farmers can be used as an indicator of economic productivity. A similar approach is followed for tomato production in the dry season. Analysis of maize gross margins indicates there is little difference in value or yield between head and tail farmers in the wet season. It is noteworthy that no head farmers grow maize in the dry season whilst all tail farmers plant maize in this season. Summer maize gross margins and yields do not differ much by location. Tail winter maize results in a drop in average yield with an associated fall in value. Results for tomato cultivation reveal only head dry season production passing a minimum sample size threshold (greater than 5 farmers) and a yield threshold (greater than 0.01 tonnes per hectare). The majority of head farmers plant tomatoes in the dry season with estimated gross returns per hectare of almost double wet season maize.

3.2.3. Crop water use and value. Following FAO (1998)\textsuperscript{16}, crop coefficients (\(K_c\)) and growing season periods were calculated to estimate crop water use for maize as the dominant wet season crop (planted mid October, 120 day growing period) and tomatoes as the dominant dry season crop (planted early April, 130 day growing period). Supplementary irrigation to summer maize is estimated at 243 mm, assuming 50\% effective rainfall and 75\% irrigation efficiency. Tomato irrigation is estimated at 448 mm with the same irrigation efficiency but no effective rainfall contribution. Scheme irrigation demand is estimated at 95\% of the DWAF allocation of one million m\(^3\) water per year\textsuperscript{17} if the full command area is

\textsuperscript{16} This is an internationally-accepted crop water requirement approach based on the Penman-Monteith equation. Most recognised models, including ACRU or SAPWAT, have this equation at their heart with modifications for local conditions and input parameters. Different models are likely to provide different water use estimates with particular sensitivity to rainfall efficiency and irrigation efficiency parameters.

\textsuperscript{17} This is based on a DWAF rule-of-thumb estimate of 10,000 m\(^3\) water per hectare.
planted with both a wet and dry season crop. This suggests the crop water use estimates are reasonable. Estimates of water use for irrigation under current conditions are 332,499 m$^3$ in the wet season (137 ha planted with maize) and 134,430 m$^3$ in the dry season (30 ha planted with tomatoes).

Water productivity (US$ per m$^3$ irrigation water) is presented for gross returns from supplementary irrigation. Gross returns from irrigation per hectare are presented for maize and tomato (based on local farm gate prices) and for a total basket of crops grown by farmers. Summer maize returns are estimated at US$0.10 per m$^3$ water for head farmers and US$0.08 per m$^3$ water for tail farmers. Winter tomato returns are US$0.10 per m$^3$ water for head farmers. Returns for a basket of crops grown in the summer season are US$0.12 per m$^3$ water for tail farmers and US$0.38 per m$^3$ water for head farmers, and US$0.58 per m$^3$ water for winter crops grown by head farmers. These findings indicate that additional water allocations to grow winter tomatoes (4,481 m$^3$ per hectare) provide no improvement on gross returns per unit of supplementary irrigation compared to summer maize. Returns to a basket of crops grown indicate higher value water use is possible given sufficient market demand. Demand-related constraints limit the sale of summer crops to between 29–54% of harvest value, subject to scheme location. There is clearly a comparative advantage of having access to irrigation for winter crops but it appears only head farmers exploit this advantage by increasing their proportion of harvest value sold from 54% to 72% compared to tail farmers who manage a minor shift up from 29% to 32% of harvest value sold. This suggests benefits of water allocation to irrigation in the summer are modest and winter benefits of irrigation mainly accrue in terms of increased aggregate income for head farmers with little improvement in economic returns per unit of irrigation water.

Comparing gross returns to the 2003 Limpopo Province raw water use charge for irrigation (US$0.001 m$^3$ water) (DWAF, 2003) suggests farmers are adding value, though current water pricing levels are considered to be under-priced and are being reviewed. For example, an economy-wide evaluation of water allocation to irrigated agriculture and plantation forestry in the Crocodile River catchment in Mpumalanga Province provides a range of gross economic values associated with value addition from irrigated sub-tropical fruits through the value production chain (Hassan, 2003). Comparing the direct value added estimates for a range of fruit tree crops indicates a range of gross returns per unit of supplementary irrigation of US$0.23–0.50 m$^3$ water. While these higher values may only be loosely compared to the Khumbe values, an important finding of the forward linkages’ analysis to the wider economy was the low additional indirect value addition from irrigated agriculture compared to plantation forestry in terms of economic and employment benefits per unit of water.

### 3.3. Irrigation scheme performance

Molden et al. (1998) developed a range of indicators to evaluate the performance of irrigation schemes. Crop yield and productivity indicators have already been presented but assessment of how an irrigation scheme may perform based on the data collated plus contemporary infrastructure costs and operation and maintenance (O&M) costs allows a comparative assessment of the financial viability of irrigation schemes. Three indicators are presented: gross return on investment, financial self-sufficiency and a repayment break-even analysis.

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18 Values reported in 1998 Rands are converted at an annualised average exchange rate of R5.55 = US$1.
O&M costs for Khumbe are borne by the local municipality and not the farmers. This effective subsidy is estimated from a proxy value of US$945 hectare per year (Molden et al., 1998). The current development of a similar size irrigation scheme further east in the Luvuvhu catchment estimates infrastructure costs at US$4,250 per hectare (Stimie, 2003). Annualized values are calculated to repay the capital cost investment over 20, 30 and 40 year periods at interest rates of 5%, 8% and 15%, respectively. This allows a sensitivity analysis between various repayment schedules (Table 5). Gross production values are used in favour of net values as they are less prone to distortions, they reduce difficulties calculating labour or opportunity cost of land, and are considered more easily comparable (Molden et al., 1998). Finally, an important caveat in terms of interpreting the findings is to be reminded of the low level of produce sold, particularly by tail farmers.

Gross return on investment is estimated as annual production value divided by infrastructure repayment cost. Head farmers record values of 1.01, 2.47 and 4.72. All these values are greater than one indicating a positive return on investment. Tail farmers record values of 0.16, 0.39 and 0.75. These returns are negative under every repayment scenario. Financial self-sufficiency is calculated by annual production value divided by O&M costs. Head farmers record a positive value of 3.73. This indicates a healthy margin above annual O&M costs. Tail farmers record a value of 0.59, which indicates a 41% shortfall in achieving a break-even financial level.

A further indicator is a repayment break-even analysis based on adding O&M costs and repayment costs to estimate a required productivity level to cover recurring costs. Head farmers record values of 0.80, 1.49 and 2.08. Whilst head farmers fail to break-even under the short-term, higher value discount rate scenario, by relaxing the repayment period and discount rate it is clear that they are able to break-even under the 30 year and 8% discount rate scenario. Tail farmers record break-even values of 0.13, 0.24 and 0.33. This indicates that tail farmers would require a substantial subsidy to break-even.

### 3.4. Irrigation and catchment water resources

DWAF (2004) estimates 59% of available annual water yield in Khumbe’s quaternary catchment (A91E) is used by commercial irrigation (34 × 10⁶ m³ per year). Water allocations to the Ecological Reserve are estimated at around 19% of mean annual runoff leaving 22% (13 million m³) of annual flows available to basic human needs, industry, storage/transfer or other claims. Exploring different land use scenarios allows improved understanding of differing social and hydrological impacts to provide guidance for decision makers. Results of land use change simulations from a neighbouring quaternary

<table>
<thead>
<tr>
<th>Table 5. Khumbe scheme performance.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wet season</strong></td>
</tr>
<tr>
<td>Head farmers (Gross US$ per hectare)</td>
</tr>
<tr>
<td>Tail farmers (Gross US$ per hectare)</td>
</tr>
<tr>
<td>O&amp;M annual costs (US$ per hectare)</td>
</tr>
<tr>
<td>Annualized infrastructure</td>
</tr>
<tr>
<td>cost repayment scenarios</td>
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<tr>
<td>(US$ per hectare)</td>
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</table>
catchment (A92A) highlight important hydrological responses to increasing irrigation land cover, particularly in comparison to forest land use change (Hope et al., 2004). Increasing irrigation land cover to 15% from 0% while holding forest cover constant led to a reduction in catchment outflow of 30 million m$^3$ water per year; alternatively, if forest cover increases from 14% to 56% cover along with 15% irrigation land cover, catchment outflow is reduced by 36 million m$^3$ water per year (Hope et al., 2004). These changes have important social, economic and hydrological impacts. First, without significant storage for drinking water supply, increased irrigation cover will result in basic drinking needs not being fulfilled one in every ten years. Second, economic analysis indicates that irrigation has shorter and lower value chains than forestry in the Luvuvhu catchment questioning the economic rationale for increasing irrigation in the catchment (Giacomello et al., 2004).

Based on ACRU simulations over a 43 year period for Khumbe’s quaternary catchment (A91E), the potential maize yield is estimated at 9 tonnes per hectare for the typical sandy clay type soils. Estimates of maize yield grown under commercial dryland practices are estimated to be an average of 5.5 tonnes per hectare and 8.7 tonnes per hectare under irrigation. By contrast, estimates of maize yield grown under subsistence conditions indicate a mean annual yield of 1 tonne per hectare. This is typical of the “yield gap” between subsistence and commercial farmers and it is this type of situation which has given impetus to movement towards improving dryland agriculture practices to ensure food security, rather than investments in irrigation schemes (SIWI, 2001). Furthermore, analyses of this quaternary catchment and those surrounding it, suggest that water use by dryland maize relative to the dominant natural vegetation in the catchment is negligible, and that it may even use less water than some of the natural vegetation of the area at some times of the year (Hope et al., 2004). This implies that there are catchment scale benefits to focussing attention on improving dryland crop and land management techniques.

### 4. Discussion

This study has considered the case of water allocation for smallholder irrigation under conditions of water scarcity. Given new and priority claims for basic human needs and ecological systems in South Africa, smallholder irrigation schemes have come under closer scrutiny from other claims for available water resources. Findings indicate that water allocation for smallholder irrigation provides expected income and food benefits for those with secure irrigation access. However, while water allocation for smallholder irrigation may be argued to be equitable within the national irrigated agricultural sector, there is unconvincing evidence to allocate water to smallholder irrigation schemes within the wider development challenges in the Luvuvhu catchment.

Improving water allocation is a key development challenge in the catchment to overcome poor levels of basic drinking water access, reduce income poverty and to improve household food security. Supporting smallholder irrigation schemes like Khumbe appears a partial and unsustainable response to these catchment management challenges for at least four reasons. First, Khumbe households are relatively wealthy in the catchment context regardless of irrigation access or irrigation land.

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19 This quaternary catchment was chosen for scenario analysis due to long term water flow data measurements. It is similar to A91E with mean annual rainfall of 859 mm.
ownership. While irrigation access increases income-generating and food security opportunities for plot owners, a lack of water access or land is not necessarily associated with household income poverty. As Smith (2004) and Hassan (2003) argue water allocation may be more usefully measured and articulated in terms of job generation per unit water. This is consistent with improving the distributional benefits of productive uses of scarce water (Quibell, 2005). Second, Khumbe irrigation plot owners may only be loosely described as farmers as the main household income sources are non-farm wage or state pension transfers. While head plot owners are estimated to generate large returns these are indicative rather than economic due to market demand constraints and a risk-averse cropping strategy. Third, though irrigation access is associated with income improvements and food security, water productivity is seen to be low and shows no difference between wet and dry seasons. It is difficult to justify water allocation for low value water use, on equity grounds, given the majority of catchment (dryland) farmers are excluded. Fourth, gender bias which excludes female-headed households’ from secure irrigation access weakens developmental arguments for water allocation for smallholder irrigation.

One water allocation approach which may contribute to the wider challenge of food security for the majority of dryland farmers at the catchment scale is improvements in dryland cultivation (SIWI, 2001; Gowing, 2002). Rainfed improvements will reach more people at lower water resource costs if simple land management innovations are introduced and adopted (e.g. conservation tillage, rain-water harvesting techniques). This will have an associated hydrological response but the magnitude of the impact is likely to be within resource constraints subject to the agro-ecological context. For example, Khumbe is located in a high rainfall area which is likely to require modest improvements in land management or supplementary irrigation to improve yields. However, communities in the north eastern drier zone, like Mutele, are unlikely to be able to support a summer crop without full crop irrigation access.

This analysis indicates that in the relatively wet areas of the upper Luvuvhu catchment, where the Khumbe scheme is situated, the cultivation of dryland maize is a viable land use with yield potential in excess of 5 tonnes per hectare per year. Significantly, the cultivation of dryland maize is considered to be hydrological neutral, as the crop uses almost the same amount of water as the dominant natural vegetation type in the catchment. This is not the case for other land uses such as commercial forestation and irrigation in the catchment, which have significant negative impacts on downstream flow (Hope et al., 2004). Given such results, catchment managers should be cautious of committing more public funds to smallholder irrigation and should instead give greater attention to the hydrological and social benefits associated with improvements in dryland farming for increasing food security under water scarcity.

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