Hum Ecol (2007) 35:113–127
DOI 10.1007/s10745-006-9095-0

Assessing the Effects of Invasive Alien Species on Rural Livelihoods: Case Examples and a Framework from South Africa

C. M. Shackleton · D. McGarry · S. Fourie · J. Gambiza · S. E. Shackleton · C. Fabricius

Published online: 29 December 2006

Abstract The detrimental impacts of invasive alien species (IAS) on ecosystem goods and services and local and regional economies are well documented. However, the use of IAS by rural communities is little understood, and rarely factored into IAS control programmes. Understanding the use of IAS by rural communities and factoring these into cost-benefit models is complex, depending upon a range of local-level attributes such as the time since invasion, abundance, and local-level costs and benefits. This paper reports on two case studies examining the role of IAS in rural livelihoods in the Eastern Cape, South Africa. In both cases, rural communities made widespread consumptive use of the IAS and generally would prefer higher densities, except in certain key localities. Several households traded in IAS products to generate supplementary income. We present a conceptual framework to guide interpretation of these and future case studies, considering attributes such as time since invasion, the competitiveness of the species, and the relative costs and benefits.

Key words *Acacia mearnsii* · benefits · costs · livelihoods · *Opuntia ficus-indica* · temporal framework · vulnerability

Introduction

Invasive alien species (IAS) are one of the biggest threats to ecosystems and biodiversity worldwide (D'Antonio and Kark, 2002) affecting the delivery of ecosystem goods and services, and consequently human well-being (Pimental, 2002). Invasive alien species can have large detrimental economic impacts on human enterprises such as fisheries, agriculture, grazing and forestry. Globally, the costs associated with such impacts of IAS has been put at US$ 1.4 trillion per year; approximately 5% of global GDP (Pimental *et al.*, 2000).

While the negative impacts of IAS on ecosystem structure and function are undisputed, understanding of their potential impacts on rural livelihoods and well-being is less developed, especially since it is their land and waters that are most affected by IAS. It is tacitly assumed that the harmful impacts on ecosystem goods and services automatically translate into negative effects on human well-being. Yet, IAS are frequently integrated into local livelihoods, both as managed species, as well as exploitation of wild invasive populations (e.g. Geesing *et al.*, 2004; de Neergaard *et al.*, 2005).

There are a number of possible pathways whereby IAS become integrated into local livelihoods. The first is the case of rural communities introducing, or accepting the introduction of, species with clear uses to them from the very outset. The initial introduction is generally within a controlled, or farming type situation, e.g. introduction of new fish species for farming, horticultural species into gardens, plantations of tree species useful for construction or firewood. Negative consequences may arise as these new introductions spread into the broader landscape away from the control of the local community, thereby undermining the livelihoods of non-beneficiaries.

The second is the situation where IAS are intentionally introduced into an area and subsequently escape, or they spread in from surrounding areas. The escaped or invading populations may not be widely used initially, but there may possibly be a threshold density of an IAS beyond which

C. M. Shackleton (✉) · D. McGarry · S. Fourie · J. Gambiza · S. E. Shackleton · C. Fabricius
Department of Environmental Science, Rhodes University, Grahamstown 6140, South Africa
e-mail: c.Shackleton@ru.ac.za

people 'switch' from favouring indigenous species to IAS. This may be because the former become too scarce and the latter abundant enough to warrant the 'switch,' so the opportunity costs of use favour exploitation of the IAS. Some of these 'switches' may lead to the active management of IAS, acting as a positive feedback on the invasion; for example the cultivation of *Ajuga sericifera* in home gardens in South Africa (Keirungi and Fabricius, 2005).

In other cases, people might simply be using an IAS because they have resigned themselves to its presence and are making the most of them, such as the use of *Prosopis* species for fuelwood and furniture in arid areas (e.g. Geesing *et al.*, 2004). In such a situation it may lack superior qualities to prompt a shift from indigenous species, but it is used as one of the goods available from the surrounding environment in more-or-less direct proportion to its representation.

The last scenario is that people simply have to live with some IAS that have no apparent uses. In the early stages of invasion its presence may pose relatively little threat or inconvenience. But as density and the extent of invasion increases it impacts on other ecosystem goods and services, and daily activities. But the rural poor typically lack the institutions, capital and/or techniques to eradicate it. In such situations the negative ecosystem costs ultimately increase the vulnerability context and thus potentially undermine local livelihoods. Examples abound, such as Triffidweed (*Chromolaena odorata*) invasion in many countries (Goodall and Erasmus, 1996; McWilliam, 2000).

In all these situations local communities have had to consider the trade-offs between the negative impacts on ecosystem dynamics and goods from the local landscape, and the potential positive benefits through use of the IAS products. Whether or not the net trade-off will be positive or negative will be influenced by a number of contextual factors; for example the extent and density of infestation, availability of alternatives, costs and mechanisms of control, land tenure, current vulnerability, discount rates, and the severity of loss of ecosystem goods. Scale of examination is crucial, with much previous work indicating that the negative costs associated with IAS are largely borne by broader society through loss of ecosystem services, but these take little account of local-level informal use and benefits from IAS (de Wit *et al.*, 2001). Hence, national or sub-national scale assessments frequently omit or underestimate local-level benefits. On the other hand, local-level users may value the benefits but have little appreciation of the wider costs. Hence, in an impartial large-scale evaluation there appears to be a classical conflict of interest, but this may not be so on the ground.

There is much understanding of the impacts of IAS on ecosystem goods and services (e.g. le Maitre *et al.*, 2002, Brooks *et al.*, 2004), although at times confused by a lack systematic adoption of standard terminology and definitions (Richardson *et al.*, 2000; Colautti and MacIssac, 2004). In comparison, there is relatively little rigorous work exploring the role of IAS in local livelihoods, other than that of Geesing *et al*. (2004), Kaufmann (2004), de Neergaard *et al.* (2005) and Siges *et al.* (2005). This imbalance is telling because, with the increasing global awareness of the negative impacts of IAS, there is greater effort to control and remove them. This has essentially been deemed an ecological issue (e.g. McDonald *et al.*, 1986), sometimes paired with an economic one (e.g. de Wit *et al.*, 2001; Pimental, 2002). When the economic costs of IAS have been considered, they have invariably been at the national or regional scale, considering losses of ecosystem services and impacts on the formal economy (e.g. papers in Pimental, 2002). Seldom have the livelihoods and needs of rural people on whose land the IAS is located been considered (McGarry *et al.*, 2005).

Within the context of the above, the objective of this study was to determine the effects of IAS infestation on human well-being, with a focus on the effects on rural livelihoods, within a general livelihoods analysis approach (Carney, 1998; Scoones, 1998). Relevant questions in exploring this objective included (1) How important, if at all, are IAS in local livelihoods? (2) What are the explicit and implicit trade-offs that rural people make regarding IAS? and (3) How do the local-level impacts of IAS undermine livelihood opportunities and resilience? In the latter instance, resilience was taken as a measure of the amount of change or disturbance represented by the IAS that local livelihoods could absorb without major shifts (Folke *et al.*, 2002). These questions were addressed through two case studies in the Eastern Cape province (South Africa), one on *Opuntia ficus-indica* (L.) Mill. and the other on *Acacia mearnsii* de Wild. In terms of this work, we followed the use of Richardson *et al.* (2000) in referring to invasive species as ones that are naturalised and that can establish offspring at significant distances away from the parent plant and so have the capacity to spread over large areas. Both of these species are considered major invaders in South Africa (Robertson *et al.*, 2003), and probably better fit the term "transformer" species (Richardson *et al.*, 2000) because they have resulted in intense ecosystem impacts over large areas (millions of hectares).

Overview of Introuction into South Africa

Prickly Pear (*Opuntia ficus-indica*) is an invasive cactus introduced from central America, and is widespread throughout the Eastern Cape. It was first recorded in South Africa in the 1700s as an ornamental garden plant of the Cape-Dutch colonists (van Sittert, 2002). It was then transported by the 1820 settlers to the Eastern Cape were it flourished as a cultivated export to England and a seasonal food source for settlers and local inhabitants. It spread as large impenetrable thickets that diminished other land use options until eventually control measures were demanded (van Sittert, 2002). Initially it was removed manually and burnt, but this was extremely labour intensive. Chemical removal with arsenic of soda was tried but was too expensive for most farmers (van Sittert, 2002). Lastly in the mid-1950s, biological controls were introduced via four different insect species, which arrested the spread of Prickly Pear, and populations are now relatively static (Zimmermann and Moran, 1991).

Black Wattle (*Acacia mearnsii*) is an invasive tree originating from Australia. It arrived in South Africa in the mid-nineteenth century and was grown in plantations for commercial timber and bark for tanning (le Maitre *et al.*, 2002). Seed from these plantations spread creating dense patches in the surrounding landscapes. It has now invaded over 2.5 million ha (de Wit *et al.*, 2001), with up to a further 8 million ha of currently natural lands at risk (Rouget *et al.*, 2002). At a national scale the costs of Black Wattle invasion outweigh the benefits of the commercial Black Wattle industry and use by rural communities by more than 2.5 times (de Wit *et al.*, 2001). The South African government and the forestry industry are now actively trying to eradicate Black Wattle invasions through sponsorship of the Working for Water (WfW) project (Binns *et al.*, 2001). This programme has been involved in the training and subsequent employment of local people to eradicate invasive plants since 1995.

Study Sites

Two study sites were selected, one for Prickly Pear and one for Black Wattle. The two villages were selected primarily on the basis of the fact we knew the area and had done previous work in the vicinity of each. During the course of that previous work, we had observed that some people did make use of these alien species, but had no knowledge of whether this was just a few people or the majority, the intensity of use (although we did have some statistics of use of Prickly Pear fruits at Tidbury), nor negative impacts at the local level. Additionally, the two species are extremely widespread in the Eastern Cape province, and are regarded nationally as a severe problem at the landscape level requiring control (Robertson *et al.*, 2003). Thus, they were deemed appropriate for the study of local-level livelihood impacts (positive and negative) and whether or not there were local-level trade-offs.

The Prickly Pear study was at Tidbury village (32°38.6′ S; 26°39.5′E) in the Kat River valley, midway between the small agricultural towns of Seymour to the north and Fort Beaufort to the south. Details of Tidbury village are summarised by Shackleton *et al.* (2002). Mean annual rainfall decreases from the upper reaches in the north in a southerly direction, being approximately 500 mm at Fort Beaufort. There is a corresponding change in vegetation from Eastern Thorn Bushveld dominated by *Acacia karroo* in the north of the valley, to more succulent thicket in the south, characterized by *A. karroo*, *Euphorbia* spp., *Diospyros dichrophylla* and *Olea europaea* (Low and Rebelo, 1996). The village comprises 42 households sandwiched between two citrus farms that provide seasonal employment from May to July. Infrastructure is poor, with no school, clinic or community hall. The majority of households (80%) rely on government grants for income (disability or child grants, old age pensions) (Table I).

Catha village is situated in the Amatola municipality, approximately 20 km from Keiskammahoek town (32°35.3′ S; 27°07.4′E). It lies at the base of the Amatola mountains and is surrounded on three sides by hills. The vegetation is a mosaic of small patches of indigenous forest, mountain grasslands and Black Wattle thickets. Mean annual rainfall is approximately 800 mm. It has an active and strong leadership and community organizations. There are two schools, a clinic, and a community hall. The roads are currently being upgraded. The Participatory Forest Management (PFM) committee is active and involved with monitoring and controlling indigenous forests and exotic timber plantations of pine, eucalyptus and wattle. Nearby,

Table I Household Profiles at the Two Study Sites

	Tidbury	Catha
Number of households	42	±300
No. of permanent residents per hh	3.7±2.0	3.6±1.5
Proportion of adult males (%)	24.4	23.8
Proportion of adult females (%)	35.4	37.0
Proportion children (<17 years old) (%)	40.2	29.2
Full time formal jobs per hh	1.0±0.23	0.2±0.4
Government grants or pensions per hh	1.1±0.8	1.2±0.7
Proportion of hh with at least one pension or gov. grant (%)	79.2	83.3
Proportion of hh with cattle (%)	29.2	36.7

the Department of Water Affairs and Forestry (DWAF) has commercial pine and Black Wattle plantations which provide some local people with employment. Households also rely heavily on governmental grants and pensions, with 83.3% of households receiving at least one pension or grant (Table I).

Approach

Data collection was contextualised within a livelihoods analysis framework, and consisted of replicate household interviews, workshops with specific user groups, key informant interviews, and estimates of IAS density.

Fifty-four household interviews were randomly selected, 24 at Tidbury and 30 at Catha. Each interview took approximately 50 min, and was conducted in the local language (isiXhosa). Interviews were with any adult members of the households, typically more than one, and focussed on the use of each IAS, trade, alternatives, attitudes towards their presence in particular landscapes, explicit trade-offs, and significance in local culture and livelihoods. Within each interview a participatory exercise was used to determine the interviewee's preferred density of the IAS. Interviewees were presented with five different pictures of the same landscape at different levels of infestation; card A indicated no IAS infestation, card B illustrating one tree per 100 m^2, C showing three trees per 100 m^2, D showed five plants per 100 m^2, scattered evenly throughout the landscape, and E showed a density of eight plants per 100 m^2 (McGarry *et al*., 2005). Respondents then had to choose their preferred density and provide reasons for their selection.

Data were collated via spreadsheets. For the collection and selling of Prickly Pear, gross seasonal incomes were calculated. The US dollar exchange rate at the time of the field work was approximately US$ 1=R6.25. Volumes of Prickly Pear used were standardized as some people collected with buckets of known volumes, and others provided actual numbers of Prickly Pear fruits; ten fruits were estimated to be the equivalent of 2.5 l. Wattle wood was collected either by head-load bundles, cattle-pulled sleds, or light delivery vehicles (LDV). Local respondents estimated that nine head-loads were equivalent to one cattle sled, and 2.5 cattle sled loads equated to one LDV load. The mass per head-load (24.3 kg) was taken from Bembridge and Tarlton (1990) who worked in the same area.

At each site workshops were conducted to triangulate the findings from the interviews and obtain different user groups' perspectives. Aspects covered in each workshop included: (1) local understanding of current legislation surrounding the controls of the IAS and opinions on such controls or lack thereof, (2) perceptions of other stakeholders in relation to either species, (3) methods developed locally to collect or prepare the species, and (4) listing of the major positive and negative factors associated with the presence of either IAS. The work with the villagers was supplemented with discussions with other stakeholders and experts operational in the area. At Tidbury this included two farmers (a cattle farmer and a citrus farmer), an agricultural extension officer and the local Nature Reserve manager. At Catha the Participatory Forest Management Committee (PFM), two tribal headmen, the oldest resident and a forestry official were interviewed.

Lastly, at each site a number of transects were sampled to determine the density of the IAS in the key areas harvested by the villagers. This was achieved using the Point Centred Quarter (PCQ) method (Mueller-Dombois and Ellenberg, 1974). Within each quarter the distance (m) to the closest IAS plant was recorded, along with its basal diameter (cm). The distance between each point was to 10 m.

Results

Prickly Pear (Tidbury village)

Size of the Invasion

There were two key harvesting sites; one 2.0 km from the village that had 2.9 Prickly Pear stems per 100 m^2, and another 2.5 km away to the south that had 4.2 stems per 100 m^2. The density of Prickly Pear around the homesteads and abandoned fields was 3.4 stems per 100 m^2 which was comparable to the density of the more distant populations. The residents used to harvest from a large population to the north, but no longer have access since it was fenced off to create a Nature Reserve. The density there was approximately 5.3 stems per 100 m^2.

Perceptions of Invasion

All interviewees said that Prickly Pear had been present before they were born. The oldest interviewee (75 years), stated that his father used to collect Prickly Pear as a young boy. In the group workshop, participants revealed that they were unaware that Prickly Pear was an alien species, and one woman insisted that it was "the plant of my ancestors." Only 4% of the people interviewed felt that the abundance of Prickly Pear had increased over the recent past (last 5–10 years), while 67% said that it has decreased. One quarter (25%) perceived the densities to have remained static. The most common reason people provided for the decrease was the higher harvesting pressure placed on Prickly Pear resulting from the loss of access to populations due to the

Table II Use and Consumption of Prickly Pear

Direct uses of Prickly Pear	Number
Hh using (%)	99
Hh collecting (%)	58
Hh purchasing (%)	8
Hh collecting and purchasing (%)	29
Mean amount used per interval (l)	15.2±8.27
Mean no. of times collected per month	3.2±2.80
Average duration of seasons (months)	2.5±0.59
Duration of collection trip (h)	3.2±2.30

creation of the Nature Reserve. Other reasons provided were lack of rain and the biological control introduced by commercial farmers who occupied the area previously.

Direct Uses

Nearly all the villagers (23 of the 24 households interviewed) used Prickly Pear fruit (Table II). Of these, 14 collected the fruit, two purchased it, and seven both collected and purchased it. Of the 21 households that collected, 86% did so from the mountains to the south. The manager of the Nature Reserve reported that people jump the fence to collect, which was later confirmed by the community representative.

During the fruiting season (mid-December–end March) one or two members of a household leave early in the morning to collect Prickly Pear on the mountains. On average, a trip took about 3.2 ± 2.3 h and the mean amount of Prickly Pear collected on each trip was 15.2 ± 8.3 l (Table III). Fruit yield per plant is highly variable in relation to plant age, size, location and level of disease. It can be up to 300 fruits per plant, but is typically much less. The collectors made 3.2 ± 2.8 trips a month. According to the interviewees the fruiting season lasted about 2.5 ± 0.6 months. Within the group workshop participants mentioned that people who collect for subsistence have priority over people who collect for selling. This is an important informal institutional arrangement to safeguard equity of access and local household food security.

Prickly Pear was also used to make wine, locally called *iQilika*. This word is not unique to Prickly Pear wine, and refers to any honey-based fermented drink. Four people were found to brew iQilika and two shared it with neighbours and relatives. Two houses also made Prickly Pear jam, and four households were found to be feeding their livestock with Prickly Pear cladodes. One person was establishing a Prickly Pear fence around his vegetable garden.

Economic Use

There were four active Prickly Pear vendors at Tidbury village (Table III). During the group workshop it was suggested that more people would be involved in selling Prickly Pear if it was more abundant as current densities were too low to support both subsistence requirements and for selling. All four vendors used the income from Prickly Pear sales to purchase groceries, and sometimes school stationary for their children. Gross monthly earnings were low, ranging from R20 to R100 (Table III). Although there were only four people actively selling Prickly Pear, four other people mentioned that they occasionally exchanged buckets of fruits with neighbours for staple foods. This was confirmed by the group workshop participants who agreed that Prickly Pear was used for barter which helped nurture reciprocal relationships within the community. Participants highlighted that those who shared Prickly Pear with others were more likely to be supported later on in times of need, i.e. the building of social capital.

Alternatives

Eight people could remember a time when Prickly Pear densities were very low, such that there was hardly any fruit. Two people out of the eight said that they used other

Table III Income from Selling Prickly Pear

	Vendor 1	Vendor 2	Vendor3	Vendor 4
Selling days per season	2	20	2	36
Volume sold per season (2.5 months) (l)	30	100	12.5	75
Unit price (R/l)	1.60 (R8 for= 5 l)	1 (R5 for 5 l)	4 (R20 for 5 l)	1.40 (R7 for 5 l)
Gross seasonal income (R) (2.5 months)	48	100	50	105
Labour time collecting per day (h)	8	2	4.5	6.5
Selling place	Roadside	Roadside	Home & Roadside	Roadside

wild species during this time. They both still used these wild indigenous species, although they preferred Prickly Pear, as the fruit is larger, sweeter, readily abundant and "it gives us more energy." Workshop participants said that although they can get other fruit, Prickly Pear was more substantial. They said that while walking in the hills they could rely on the other wild fruits for a snack, but they will make special trips to collect Prickly Pear to bring home.

Optimal Densities

At Tidbury village 92% of people wanted Prickly Pear at the highest possible densities. Reasons for this included: (1) they loved it and wanted more, (2) such densities would provide enough fruit for more people to sell, (3) it would reduce the distance required to walk to find sufficient quantities, (4) it was "beautiful to look at," and (5) it was a useful supplementary food. When asked if there were sites at which they would not like Prickly Pear, 46% of respondents stated that they would not want it growing within their homesteads and gardens; 13% did not want any near rivers or sacred pools; and 8% in fields and grazing lands. The remainder (33%) wanted it everywhere. The most common reason for preferring it not too close to homes was that the thorns were dangerous to children. The reason for not wanting it in dense stands in the grazing lands was because it would reduce the already limited grazing. One man said that he would prefer the Prickly Pear to grow in areas where there was erosion to protect the soil.

Cultural Value and Integration

Two people said that Prickly Pear had a cultural value because it signified a relationship with the spirits. In the group workshop a traditional healer mentioned it was useful to ease chest pains. Six people said that Prickly Pear grew on the riverbanks near sacred pools which upset the ancestral spirits who reside in the pools.

Besides attaching a local name (*itdlofiya*) to Prickly Pear, residents had also developed local techniques and terms associated with Prickly Pear. Most (95%) used a specific technique to avoid injury from the spines, the most common being a piece of wire bent into a hook (called *umgwewe*) to collect fruits high up on the plants. The second most common technique was the use an old soft drink can with one of the sides cut off (called *itanki*), to break off the fruits.

Alternative Stakeholder Impressions

The Nature Reserve manager did not consider Prickly Pear as a problem in the reserve at its current densities. However, he felt that when villagers jumped the fence to collect Prickly Pear that they were in danger of being attacked by wild animals. He had instituted a controlled permit system. Both the citrus farmer and the cattle farmer did not consider the Prickly Pear a problem, and stated that the current densities were too low to have any negative effects on the functioning of their farms. Instead they recognised the value of Prickly Pear to surrounding communities, some of whom worked on their farms. They both felt that the Prickly Pear was an important social and economic resource and that it should be protected for the people in the valley. The citrus farmer hires many people as casual labour during the picking season (winter), and felt that Prickly Pear provided a useful food alternative during the summer season. The agricultural extension officer was not aware that Prickly Pear was an alien plant, and he personally considered it a valuable resource to the local communities. He felt that densities were too low, which he attributed to the biological control measures introduced by commercial farmers in the past. He saw a need for higher densities of Prickly Pear since it can be sold and used to supplement meagre incomes.

Other Invasive Alien Species

Although Prickly Pear was generally perceived as beneficial, other IAS were identified as problem species. All mentioned the Jointed Cactus *(Opuntia aurantiaca)* as a problem to livestock and people. They said that children were particularly prone to injury when they played barefoot in the fields. Livestock had also suffered injuries, which at times were fatal. At one stage the villagers had decided to eradicate it, and had collected as much Jointed Cactus as they could and then burnt it. But after some time it was back at the pre-burning densities and they had given up trying to control it. Black Wattle was also seen as a problem in the Kat River valley. A nearby community had sold their Black Wattle forests to a private contractor so to encourage regrowth of tree species. The agricultural extension officer mentioned a community who were struggling with a Black Wattle infestation along the river banks.

Black Wattle (Catha village)

Size of the Invasion

The Black Wattle occurred in three major areas around Catha village. The first is a 57 ha area with a density of 19.1 trees per 100 m^2. This has been set aside for a small development project controlled by the PFM committee. The second is a 27 ha patch (15.3 trees per 100 m^2) that has been delimited for peoples' daily use. The third stand runs along the river for about 5 km, and creates a 50 m band on either side of the river. It had a density of 11.9 trees per 100 m^2. This Black Wattle forest is not managed and is believed to be increasing in density every year. Young Black Wattle plants are scattered throughout the grazing lands and ploughed fields.

Perceptions of Invasion

Most (77%) respondents perceived Black Wattle to have arrived before they were born. The remaining 23% said that the Black Wattle had arrived later, with the date ranging between 1926 and 1970. The oldest informant claimed the Black Wattle came from settlers from Cathcart over the mountains in the late 1920s. All interviewees were aware that Black Wattle was an alien species. All claimed that Black Wattle had increased over the recent past. Of these, 73% blamed the rapid expansion on the prolific wind dispersal of the seeds; whereas 13% believed that the current eradication of Black Wattle by the Working for Water programme was actually assisting its growth rather than reducing it. Another reason suggested for the increase was that the area has fertile soils and high rainfall, which together promote its growth and spread.

Direct Uses

Nearly all households (96.7%) collected Black Wattle for fuelwood and building/fencing poles. Of the users, 83% collected their own supplies, and 17% purchased them. The purchasers were all elderly women who all said that they were too old to collect it for themselves. Wattle prices ranged from R80 to R200 per sled load (one cattle-drawn sled holds approximately 218 kg) with a mean price of R170 per load. Fuelwood collection occurred more regularly than the collection of building and fencing poles (which were collected when people felt they needed to repair a house, or re-fence their garden). Access to draught cattle or LDVs also influenced the amount and frequency of collection because ownership of these assets meant that they could collect and transport greater quantities. People who collected head-loads collected 3.3 ± 4.5 times a month (the equivalent of 80.2 kg); whereas those collecting with LDVs and cattle collected 0.4 ± 0.7 times a month (the equivalent of 87.2 kg) (Table IV). Collection trips lasted on average 2.6 ± 1.2 h (Table IV). Several respondents (30%) said that they used more during winter, and one person said they used more during traditional ceremonies. Although there were five women purchasing Black Wattle, there were no sellers within the interview sample. During the workshop, people admitted to offering their services to collect for others, usually men would collect for older women. Sometimes older women would pay, but people who helped did not expect payment and said that they usually did it for their relatives.

Table IV Monthly Consumption and Time Spent Collecting Black Wattle

	Head-load	Cattle-load
Mean amount used per month (kg)	24.3±12	218.25±12
Mean no. of times collected per month	3.3±4.5	0.4±0.7
Average duration of seasons (months)	Year round	Year round
Duration of collection trip (h)	2.6±1.2	2.6±1.2

Alternatives

All the people interviewed claimed they were using Black Wattle because it was located close by and that there are government restrictions on using indigenous species. Sixteen alternative indigenous species were identified, and two exotic alternatives. Approximately 60% of the respondents preferred Black Wattle over the indigenous species, because they had open access to it and it was closer to collect (potentially signifying a threshold density?). The remaining 40% preferred indigenous species over Black Wattle because Black Wattle is a softer wood and therefore doesn't burn as long as indigenous wood. No other IAS were identified as a problem within the area.

Optimal Densities

The optimal densities preferred by the Catha villagers were varied. The highest density (*E*) was preferred by 53% of respondents (men and women), the main reasons being that the more Black Wattle there is, the more would be available for people to use at home and for small businesses. Density '*D*' was the next most preferred, chosen by 23% of respondents. This group felt that the highest density was too much because (1) it would be difficult to walk in the surroundings areas, (2) the area of grazing land would be impacted too greatly and (3) criminals hide in the thicker forests. The third most common choice (10% of respondents) was to have no Black Wattle at all because they were afraid of criminals within the Black Wattle forests. Stories were common of women and children being attacked when they go down to the river to collect water and wash.

Cultural Value and Integration

The Catha inhabitants did not commonly view the Black Wattle as a cultural resource; however 27% claimed they used it to build *abakweta* huts for young male initiates, for their coming of age ritual and circumcision camps. Another man said that it was culturally significant as they used the wood for fires for weddings, funerals and other ceremonies. A traditional healer stated that Black Wattle has no cultural value and that its presence near the sacred pools upsets the ancestors. Most respondents (77%) were concerned with the growth of Black Wattle around sacred pools.

Alternative Stakeholder Impressions

The two headmen interviewed at Catha felt that Black Wattle should be removed, because its current densities were creating problems in grazing lands and fields. They also mentioned theft of cattle in Black Wattle thickets and confirmed the attacks on women and children in areas of dense Black Wattle. They also mentioned that it was difficult to control and they felt that current controls by the government, instead of reducing Black Wattle, were exacerbating the infestation. The PFM committee took a very different standpoint; they felt that Black Wattle densities should be increased in woodlots. They were planning a development project to sell Black Wattle timber. They felt that the problem of criminals could be addressed if Black Wattle was actively managed by community members. The forestry official shared similar aspirations to the PFM committee and also felt controls were needed for Black Wattle growth.

Discussion

Impacts on Rural Livelihoods

The people at Tidbury appear to rely heavily on Prickly Pear, despite it being only a seasonal resource for 2.5 months of the year. Secondary benefits of fodder are available year round, albeit little used. Prickly Pear has been growing in the area for over 200 years (van Sittert, 2002), and its adoption into everyday life at Tidbury is obvious. People in Tidbury were unaware of its alien status, and some showed offence when this was suggested. The community has evolved a specific harvesting style and tools to collect Prickly Pear. They have created new products such as Prickly Pear wine and jam from the fruit. The fruit was also sold for supplementary income by 17% of households. People favoured Prickly Pear over wild species, as also reported by Shackleton *et al.* (2002). The community felt that current densities were too low and they would prefer thick stands of Prickly Pear on the mountains, but not around their homesteads. Its role in supporting community relationships and nurturing reciprocity with the exchange of other food items for buckets of Prickly Pear is valuable, especially for the poorest households as it allows them to exchange their labour for food in the absence of cash income. It thus acts as both a direct and indirect form of local security, in common with other wild collected, but indigenous, species (Shackleton and Shackleton, 2006). Another indirect value of Prickly Pear was its aesthetic appeal for some.

The trade-offs people made when allowing Prickly Pear to grow in their lands were seemingly minimal. The potential costs associated of having Prickly Pear in higher densities are reduced grazing land, possible reduction in abundance of indigenous species, and thorns endangering children. In return people at Tidbury had a reliable seasonal food source, economic and social safety-nets for 2–3 months of the year, and enhanced aesthetics for some. At current densities the IAS poses little threat, and requires minimal sacrifice by other land users for it to persist in their environment. It is unlikely to increase in density due to the effects of several biological control agents. The challenges people face are not the possible reduction of alternative livelihood strategies and resilience, but are rather related to the low densities of Prickly Pear itself, especially due to the inaccessibility of larger populations in the Nature Reserve. A decrease in abundance would be of concern to Tidbury villagers. All in all, the number of benefits from its presence, as perceived by the people themselves, outnumbered the list of negatives (Table V). All in all, the presence and use of Prickly Pear has decreased household vulnerability to a certain degree, largely through a safety net role (Shackleton and Shackleton, 2004; Paumgarten, 2005) rather than through asset accumulation.

In contrast to Prickly Pear, a significant proportion of respondents felt that the densities of Black Wattle were too high. Yet some did want higher densities so that they could develop income-generating projects, or more jobs through the local Working for Water IAS eradication programme (which has a strong gender equity dimension and so employs both females and males). Similar sentiments were expressed by respondents in the study of de Neergaard *et al.* (2005) who examined use of two wattle species in the Drakensberg mountains. Black Wattle was viewed as a year round resource, readily available for fuelwood, building and fencing. Although people voiced their appreciation of these benefits, there were areas in the landscape where Black Wattle growth was deemed undesirable; including homesteads, grazing areas, riverbanks and sacred pools, as it reduced the productivity, cultural heritage or safety in that particular area. The latter two are particularly susceptible to invasion by Black Wattle. The costs of these benefits were not only felt by those who used Black Wattle but by all villagers, especially women and children, who faced possible attack or rape from criminals hiding in thick stands of Black Wattle. Such a finding was also reported by respondents in the study of de Neergaard *et al.* (2005). The impacts on the cultural heritage of Catha was significant, with almost the entire riparian strip clogged with Black Wattle, making it difficult to water livestock and rendering sacred pools inaccessible. Traditional beliefs in the area around water spirits in scared pools are strong (Fox, 2005), and thus infestation of the riparian strip by dense stands of

Black Wattle is viewed with disquiet. Given the low proportion of households with livestock, this is of less community-wide concern. Additional costs included the labour required to constantly remove new saplings from arable fields and the reduced productivity of grazing lands. The benefits of Black Wattle as (1) a year round resource, (2) that is located reasonably close, and (3) serving as a buffer to heavy harvesting of indigenous trees for similar uses (although the invasion itself will reduce recruitment and establishment of indigenous species), need to be considered against the costs. However, for most people, the direct use benefits currently outweigh all the costs (Table V). Overall, use of Black Wattle for construction allowed development of physical capital as well as firewood and some supplementary income. The PFM committee hopes to develop significant household enterprises based on marketing Black Wattle timber, which would increase cash incomes and potential asset accumulation.

Considered together, the two field studies show that the effects of IAS on rural livelihoods are complex. Some households make extensive use of IAS and others do not; some use it to generate income and others turn to these species only in times of particular need. In each instance some respondents felt that current densities of IAS were too high and should be reduced, either for aesthetic or economic reasons, whereas the majority would welcome greater densities because of their direct uses or income potential. Consequently, from the findings of both case studies, it is clear that the label of a “pest” for an IAS is a culturally, socially, and economically specific judgment, and that the difference between ‘nuisance’ and ‘useful resource’ is perhaps a matter of perspective and scale. This is an important reality as biological invasions of alien species are a historical process, which are not solely directed by the biology of the invader, but by shifting cultural values of the invaded society (van Sittert, 2002).

Temporal dimensions and thresholds were not easy to elucidate. It is noteworthy, however, that both species have been features of the landscape for at least two generations, such that local people had become acclimatised to them, and viewed them as an integral, if not natural, part of the landscape. Thus, it is not a case of opportunistic use, but a long-term adaptation to a permanent feature of the landscape, aesthetically, functionally and economically. Hence, livelihoods will be affected if the IAS were to be removed. There did not appear to be too many explicit trade-offs as reported by the rural people themselves.

It is clear that IAS are rarely uniformly problematic or uniformly beneficial to entire geographic communities. This is because geographic communities are not homogenous and

Table V Summary of Positives and Negatives of IAS Infestations at Tidbury and Catha

Prickly Pear at Tidbury		Black Wattle at Catha	
Positives	Negatives	Positives	Negatives
Seasonal fruit that is tasty & supports diets & nutrition	Thorns are a possible danger to children	Wattle forests are closer than indigenous forests	It is very invasive & creates difficulties when ploughing
Fodder for cattle during difficult times	Far to collect	Acts as a buffer to over harvesting of indigenous trees	Very dense near river, preventing access to the water & harbouring criminals
Aesthetic value	Denied access to populations of Prickly Pear within Nature Reserve	Possible resource for a small development project selling timber	Invasion reduces the area of grazing land
Cash income from selling fruit	Eating too much causes constipation	Resource available year round, and plenty of it	Wood burns to fast
Drought resistant so an important famine food		Used to build traditional huts for initiation ceremonies	Reducing cultural value of sacred pools
Traditional wines and jams can be made		Favoured building material for housing and fencing because the poles are straight	It uses a lot of water from the river
Exchange of buckets of fruit for other forms of food		Firewood for general use & traditional ceremonies, rituals & celebrations	
Supports community relationships and nurtures reciprocity		Protecting sacred pools from over use	
Some spiritual value, “plant of my ancestors”			

because infestations vary in density and extent. Households differ in a multitude of ways, significantly so on the duration of residence in the area, livelihood strategies, wealth, education, and adherence to cultural norms. Consequently, an IAS that has negative consequences for one group of rural stakeholders may have either a neutral or positive impacts for others. Prickly Pear neatly illustrates this. For some, mostly those with livestock (the minority), Prickly Pear has a negative impact by decreasing the area of land for grazing. But for another group, it represents a source of income from trade in the fruits at a vital time of the year (just after Christmas expenses, and those associated with the start of the new school year). For the majority, they have relatively neutral perceptions; they have few or no livestock, and they do not trade in the fruits, but they do enjoy eating the fruits when they come across them.

Both case studies illustrated that the IAS in question was used by rural communities. Yet the nature of use was very different between and within communities. Some households trade in IAS and therefore the benefits and losses experienced might be captured in local economic surveys and statistics. But for the majority of people within each case, the uses are primarily at the household subsistence level or very local-level trade. Such uses are rarely included in regional or local statistics, a problem frequently commented upon in livelihood valuation studies (Campbell *et al.*, 2002). Thus, to regional and national officials, there is little evidence, and therefore appreciation, of the range of benefits rural communities secure from IAS. Hence, the design and implementation of IAS control programmes are informed by the long-term costs of IAS for broader society and ecosystems and are rarely informed by the current needs of rural people.

Rural communities display a remarkable adaptability and opportunism to IAS. This is not to say that IAS represent only positive benefits for rural communities; several negative impacts were identified. But both case studies illustrate how rural communities adapted to the presence of the IAS in order to optimise potential benefits or minimise potential negatives. This might be a small change in the calendar of seasonal events to allow time for harvesting and processing, or storage of a seasonal product from the IAS. Other strategies are the changing of land use patterns to accommodate the IAS, such as using the IAS as a boundary marker between properties or fields, or changing the location of arable fields, or areas where livestock are grazed. On the technical innovation side harvesters of Prickly Pear have a number of wire tools for dealing with the prickles, along with local names for the new tools. Others have also reported innovations to optimise use of IAS. For example the development of a new trawl net for invasive Nile Tilapia in Colombia (Gil-Agudelo *et al.*, 2005), and the recent innovation of marketing furniture made from *Lantana camara* in India demonstrates a whole array of technological adaptations and innovations (Kannan *et al.*, 2005). Clearly, any changes and innovations lend a temporal dimension to the study of IAS impacts on rural livelihoods, especially as it is likely that such innovations only evolve after a period of time and exposure to the IAS. Thus, some studies may show little or no adaptation, but it may be only a matter of time.

From these case studies, and others (e.g. McWilliam, 2000; Geesing *et al.*, 2004), little evidence exists of local communities undertaking systematic and concerted efforts to remove IAS. This is despite negative ecological impacts, which in many instances, they had noticed and commented upon. Three postulates can be advanced with respect to this. First, the local-scale benefits of the IAS substantially outweigh the negatives. Second, the IAS offers some direct use and/or trade benefits, and that given the often precarious nature of rural livelihoods and the limited opportunities open to them, rural households seek to optimise the current benefits rather than worry about the potential ecological degradation that may occur in the future. This relates to the often survivalist modes of many rural people, and the discounting of future benefits (Campbell *et al.*, 2002). The last is that rural communities appreciate the potential or real negative ecological impacts, but are relatively powerless to do anything about it. They lack the capital, information and/or institutions to initiate and maintain effective control programmes. This is illustrated by the temporary local level attempts by the Tidbury community to remove Jointed Cactus.

Given the paucity of such work previously, it is important to consider lessons for future case studies, especially in terms of approach and a conceptual framework. Such a framework is necessary to unravel and interpret the complexity inherent in examining the effects of IAS on rural livelihoods. This complexity is a result of the (1) the varied nature of IAS and their uses, (2) the diversity of livelihoods options in which rural households engage, (3) the temporal dimension to invasions and hence people's reaction to them, and (4) the local and national contexts that shape people's options and vulnerabilities. The complexity is compounded when these different dimensions interact.

A Conceptual Framework for Interpreting the Impacts of IAS on Rural Livelihoods

The proposed framework is simplistic to make it adaptable for different types of IAS, situations and scales of measurement. Four curves are presented as trajectories through time since the IAS has been introduced (deliberately or accidentally) into an area. The first curve is one of increasing abundance of the IAS with time; it follows a density-dependent logistical function (sigmoid shape) in the absence of any control mechanisms. The second curve depicts benefits (if there are any) accruing to local livelihoods from the IAS. This will generally mirror the abundance curve. The more of the resource, the greater will be the potential benefits. The third curve is one relating to costs. This includes all costs, such as ecological costs, aesthetic costs, harvesting costs, costs of control, etc. These costs compound as time and abundance of the IAS progresses, and hence the curve is exponential. The fourth curve illustrates livelihood vulnerabilities associated with IAS. We present it as concave, with livelihood vulnerability being inherently high for most rural households (Kaimowitz, 2003) at the start. This decreases as the benefits of the IAS offer new livelihood opportunities and potentially capital accumulation whilst the costs are still low. But as costs increase relative to the benefits then vulnerability is exacerbated once more. Whether or not it exceeds the starting point will depend upon the final ratio between costs and benefits. Whether or not the ratio of costs to benefits becomes, or remains, negative will depend upon the relative magnitudes and new uses or innovations. This baseline framework is presented in Fig. 1.

Two aspects of the framework are fundamental. Firstly, inherent in each of the curves are thresholds—points at which the rate of response over time changes markedly. Additional thresholds are possible at intersections between curves. Identification of such thresholds in reality and the local community responses to such thresholds is necessary to developing a predicative understanding of the impacts of IAS on local livelihoods. Secondly, the temporal dynamic of IAS impacts is captured along the *x*-axis. Therefore, it is necessary that researchers and communities can verify where along this axis they are at any moment. For ease of interpretation and characterisation, we have divided the temporal axis into three phases, but in reality it is a continuum. Phase 1 represents the early stage of invasion represented by a low abundance of the IAS. In this situation the benefits (if any) are low, or small and direct, specifically for the reasons for which it was introduced, and probably accessed by only a small proportion of the community. There are no control attempts and ecological costs are still small. Livelihood assets and vulnerability are defined more by other livelihood issues than by the IAS.

In Phase 2 the abundance of the IAS has increased, and continues to do so. Most people are now well aware of the presence of the IAS in the landscape and/or people's fields and gardens. If it has beneficial uses (not all IAS do), many people are now accessing them. This may have prompted technological innovations or changes in livelihood patterns. Costs are increasing. The ecological costs specifically may be approaching or surpassing key thresholds of change. It is towards the end of this phase that management interventions are usually considered. These interventions may be complex, and are not always driven by local communities, but perhaps also by outside agencies, particularly conservation or State agencies. Livelihood vulnerability is reduced through the widespread use of new opportunities and benefits offered by the IAS.

Phase 3 is the one at which we anticipate the costs to eventually exceed the benefits, with the ratio becoming increasingly negative unless either the IAS is controlled (at a cost) or new and significant benefits are identified. People are now faced with either (1) controlling the invasion, or (2) living with it resulting in impaired livelihood options and increased vulnerability. The final trajectories in Phase 3 will depend upon what intervention or strategies are adopted. If costs are not addressed then vulnerability will increase to levels above that experienced before the IAS was introduced.

Accounting for IAS Characteristics

In any temporally dynamic model the shapes and steepness of the curves of costs, benefits and abundance will vary between species and between geographic localities. It is

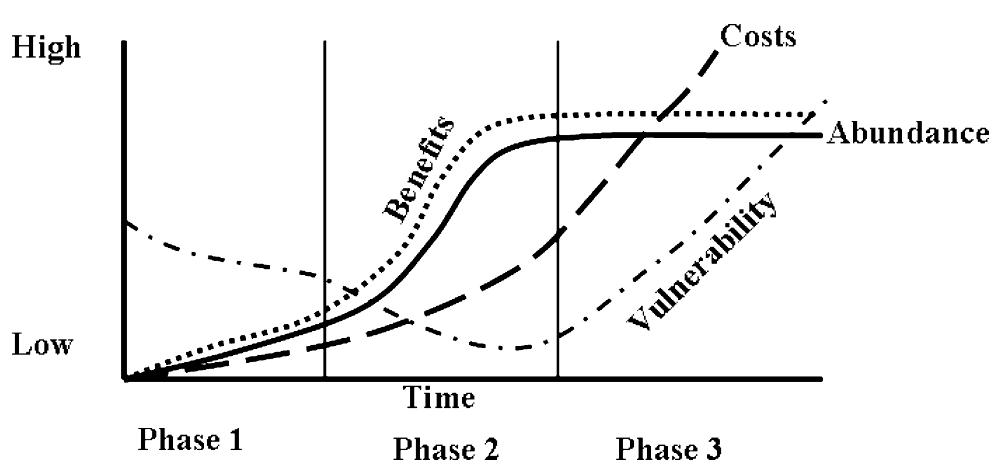

Fig. 1 A conceptual framework to interpret impacts of IAS in rural livelihoods.

instructive to classify species into four types based on a 2× 2 matrix (Table VI) of (1) invasion aggressiveness as manifest through its competitive ability and rate hence rate of spread, and (2) presence or absence of desirable traits (such as edible fruits, wood for timber, medicinal properties). The resulting four different species categories introduce four variations of the conceptual framework, which can then guide interpretation of the current impacts of IAS on rural livelihoods (Fig. 2). Field methodologies should then be orientated to determining in which phase along the time axis is each study community, as the impacts on rural livelihoods differ in each phase.

Each of these models is described in turn below. In each instance the temporal dimension is considered through examining the abundance, costs, benefits, and consequent livelihood vulnerability in each of three phases of IAS invasion.

Useful and Highly Competitive Species

In Phase 1, the early stages, the abundance of the IAS is low. People are only just beginning to notice the foreign species in their environment, whether deliberately introduced or by invasion from elsewhere. Use of the IAS is opportunistic and rare. As a highly competitive invader the costs to surrounding environments increase quickly. In Phase 2 the benefits rise with abundance of species, as locals begin to increase their use of the species and its integration into livelihood strategies. New technologies are most likely to be developed in this phase. Costs increase rapidly due to its rapid and strong invasion potential. In Phase 3, the benefits decrease as the IAS threatens other livelihood activities and perhaps goods and services from the local environment. As costs continue to rise the net cost-benefit ratio escalates. People may then attempt to control the IAS, usually with outside help, or change land use patterns. Depending on the interventions introduced in this phase benefits may increase (for example through finding a new use for the IAS, or use on a larger scale through regional markets), or decrease as control operations remove it. The cost-benefit ratio can revert back to that more typical of the early stages of Phase 2.

Undesirable and Highly Competitive Species

In Phase 1, the early stages, the abundance of the IAS is low. People are only just beginning to notice the foreign species in their environment, probably the result of invasion from surrounding regions. There are no apparent uses for the species. In Phase 2, it spreads rapidly due to its competitive nature. Awareness of the IAS increases as it becomes first a nuisance, and later on a significant hindrance to local livelihood activities and options. Costs increase quickly, slowly reducing the productivity of other resources, and hence vulnerability increases. In Phase 3, the costs reach a negative threshold, and people begin to try to control the IAS, if it is within their means to do so. Control measures may occur earlier depending upon the rate at which costs escalate.

Useful and Weakly Competitive Species

In Phase 1, the early stages, the abundance of the IAS is low. People are only just beginning to notice the foreign

Table VI Two-by-two Matrix of Species Competitiveness and Usefulness

		Competitive ability	
		Weak	Strong
Beneficial traits	Low	Undesirable, weakly competitive species It has negligible or low impact on rural people, because its invasivity is low. Hence, it is easily controlled, although such control does represent a cost. It currently has no known use and hence no benefit curve.	Undesirable, strongly competitive species The species has no or limited direct or indirect benefits to people. It invades rapidly, and is often difficult to control. The impacts on rural livelihoods will be most severe in the later phases of invasion. Rural communities are frequently unable to control it without external help.
	High	Useful, weakly competitive species Not very invasive, it is easy to manage. Benefits can be extracted from it and hence rural people with limited livelihood options will exploit it to maximum benefit. Such exploitation will be sufficient to keep it in check in most situations.	Useful, strongly competitive species Such species invade the landscape or streams rapidly, and thus are often difficult to control. They are useful to the invaded society and hence there is resistance to its complete removal. However, harvesting by dependent communities is an inadequate control measure and so abundance and concomitant ecological costs increase with time. People would like to be able to limit the species to a farming situation. Landscape invasion usually requires some external agency to assist in control.

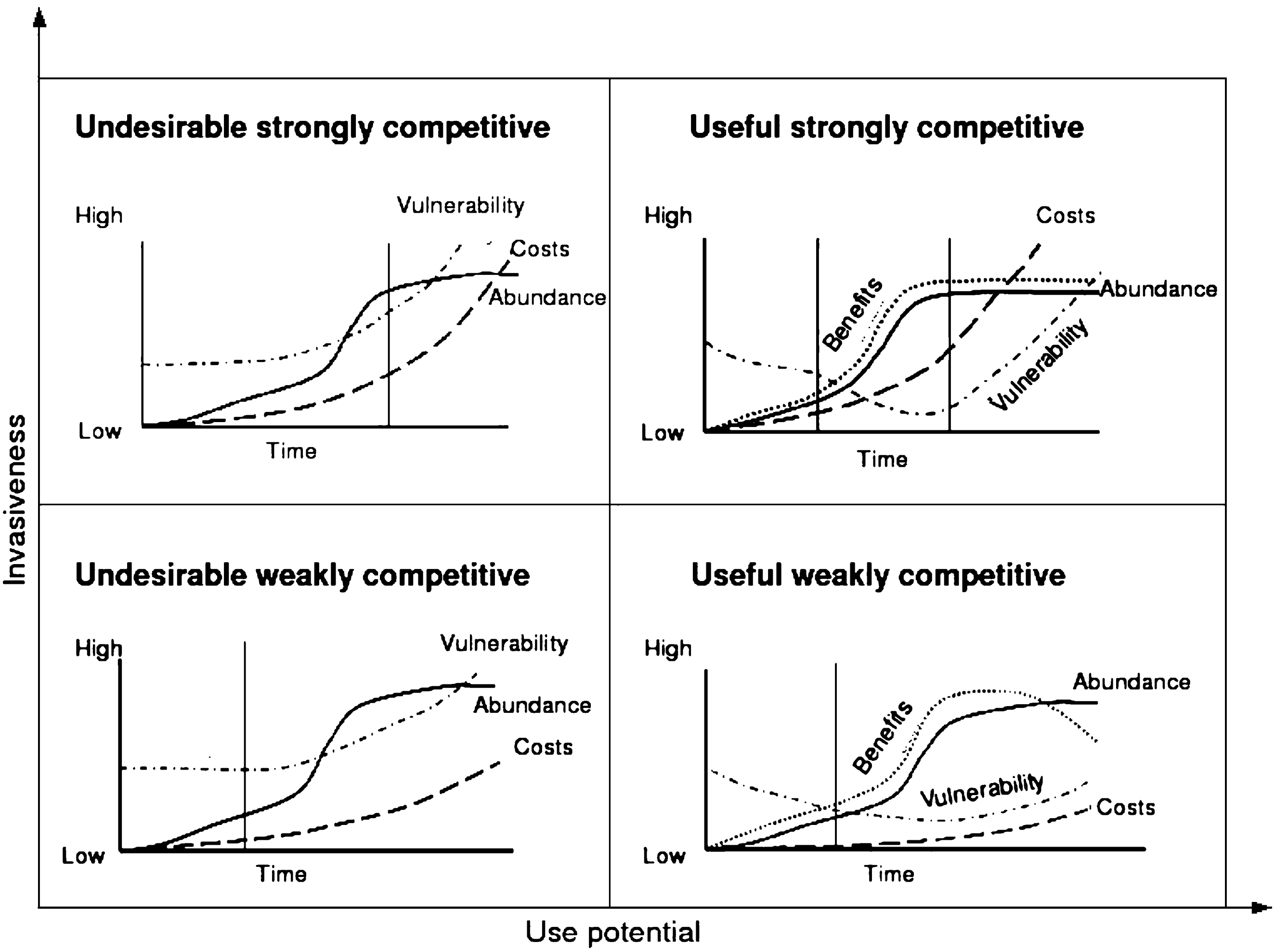

Fig. 2 Variations of the conceptual framework for different species types. (Note that the *x*-axis is longer for weakly competitive species as it takes longer for effects to occur).

species in their environment. Use of the IAS is opportunistic and rare. Because the species is a slow invader, the costs to the surrounding environment lag behind benefits. In Phase 2 benefits rise with the slowly increasing abundance of species. The IAS is adopted as a resource and possible livelihood strategy by a significant proportion of the community. Local knowledge of the species accumulates and related innovations and techniques may develop. Costs increase slowly levelling off the benefits. Vulnerability is reduced as long as benefits outweigh costs. If benefits are sufficiently high, the harvesting pressure may be adequate to keep the spread of the IAS in check. Phase 3 is typified by a static balance with no or little spread of the IAS and continued use. It is now an integral component of local livelihoods.

Undesirable and Weakly Competitive Species

In Phase 1, the early stages, the abundance of the IAS is low. People are only just beginning to notice the foreign species in their environment, probably the result of invasion from surrounding regions. In Phase 2 it spreads slowly, becoming a minor pest in the area. If no control mechanisms are introduced it continues to spread, albeit slowly, and so costs increase. With no benefits to rural livelihoods, a threshold is attained sooner or later at which the density or extent of invasion has measurable impacts on livelihoods and vulnerability, at which stage people begin to try to control the IAS if it is in their means to do so. Control measures may occur earlier due to its lack of benefits, and dependent upon the rate at which costs escalate.

Using the conceptual framework six steps can be identified for future assessments of the impacts of IAS in rural livelihoods. The framework can be applied at a range of scales. However, the preferred scale is at the level of a geographically defined community, but with provision for focus on particularly vulnerable sub-groups if such groups are identified during the participatory process. The steps include: (1) Determine if the species is a relatively aggressive or only weakly competitive, (2) Determine if the species has relatively significant or minor uses, (3) Using the information from the previous two steps classify the species into one of the four categories (Table VI), (4) Use the species classification to select which model framework to use (Fig. 2), (5) Using the model framework, collect appropriate data to facilitate determination of which phase of the framework the project community/ies is in (the model framework dictates which of the curves need to be populated), and (6) Using the data from the area, classify the local situation into one of the three phases. This will then indicate the relative degree of vulnerability of the local community to the impacts of the IAS on their local livelihoods and whether or not it is likely to change (depending upon what phase they are in).

In conclusion, this work has demonstrated that the effects of IAS on rural livelihoods are complex and spatially and temporally variable. There is a need for a larger suite of case studies using similar approaches and/or data to unravel some of the complexity and develop predictive typologies and capacity. Until that is achieved, it is important to accept that whilst the negative impacts of IAS on ecosystems are well recognised, one cannot assume that those negative impacts are automatically translated into detrimental impacts on rural livelihoods as perceived by rural people. In many instances rural people make extensive use of IAS and they perceive them to be a benefit to their own livelihoods, but this will depend upon which phase of the invasion cycle they are currently in. In some instances they prefer the IAS to indigenous species. Provided that the ecological and other costs are less than these benefits then there would be some argument for maintaining specific IAS at specific localities, especially for the most vulnerable communities and households. This can only work if the further spread of the IAS beyond the community is restricted by local use.

Acknowledgements We are grateful to the communities of Tidbury and Catha for their willingness to host the research team and share their knowledge and perceptions so openly. Thanks are due to the South African Biodiversity Institute for funding this work.

References

Bembridge, J. J., and Tarlton, J. E. (1990). Woodfuel in Ciskei: A Headload Study. *South African Forestry Journal* 154: 88–95.

Binns, J. A., Illgner, P. M., and Nel, E. L. (2001). Water Shortage, Deforestation and Development: South Africa's Working for Water Programme. *Land Degradation & Development* 12: 341–355.

Brooks, M. L., D'Antonio, C. M., Richardson, D. M., Grace, J. B., Keeley, J. E., di Tomaso, J. M., Hobbs, R. J., Pellant, M., and Pyke, D. (2004). Effects of Invasive Alien Plants on Fire Regimes. *Bioscience* 54: 677–688.

Campbell, B. M., Jeffery, S., Kozanayi, W., Luckert, M., Mutamba, M., and Zindi, C. (2002). *Household Livelihoods in Semi-arid Regions: Options and Constraints*. CIFOR, Bogor, p. 153.

Carney, D. (1998). *Sustainable rural livelihoods: What contribution can we make*? Department for Internal Development, London.

Colautti, R. I., and MacIsaac, H. J. (2004). A Neutral Terminology to Define 'Invasive' Species. *Diversity & Distributions* 10: 135–141.

D'Antonio, C. M., and Kark, S. (2002). Impacts and Extent of Biotic Invasions in Terrestrial Ecosystems. *Trends in Ecology and Evolution* 17: 202–204.

de Neergaard, A., Saarnek, C., Hill, T., Khanyile, M., Martinen Berzosa, A., and Birch-Thomsen, T. (2005). Australian Wattle Species in the Drakensberg Region of South Africa—An Invasive Alien or a Natural Resource? *Agricultural Systems* 85: 216–233.

de Wit, M. P., Crookes, D. J., and van Wilgen, B. W. (2001). Conflicts of Interest in Environmental Management: Estimating the Costs and Benefits of a Tree Invasion. *Biological Invasions* 3: 167–178.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., and Walker, B. (2002). Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *Ambio* 31: 437–440.

Fox, H. 2005. *The Benefits and Services of a Socio-economic Landscape*. Masters thesis, Rhodes University, Grahamstown.

Geesing, D., Al-Khawlani, M, and Abba, M. L. (2004). Management of Introduced *Prosopis* Species: Can Economic Exploitation Control Invasive Species? *Unasylva* 217: 36–44.

Gil-Agudelo, D. L, Narváez, J. C., Blanco, B. J., and Efraín Viloria, M. (2005). Nile Tilapia (*Oreochromis niloticus*, Linnaeus, 1758) in the Ciénaga Grande de Santa Marta and Pajarales Lagoon Complex, effects on natural ecosystems and human communities. In McGarry D., Shackleton C. M., Fourie, S., Gambiza, J., Shackleton, S. E., and Fabricius, C. F. (eds), *A Rapid Assessment of the Effects of Invasive Species on Human Livelihoods, Especially of the Rural Poor*. South African National Biodiversity Institute, Kirstenbosch, p. 210.

Goodall J. M., and Erasmus D. J. (1996). Review of the Status and Integrated Control of the Invasive Alien Weed, *Chromolaena odorata*, in South Africa. *Agriculture, Ecosystems & Environment* 56: 151–164.

Kaimowitz, D. (2003). Not by bread alone... Forests and rural livelihoods in sub-Saharan Africa. In Oksanen, T., Pajari, B., and Tuomasjakka, T. (eds), *Forests in Poverty Reduction Strategies: Capturing the Potential*. European Forest Institute, Torikatu, pp. 45–63.

Kannan, R., Aravind, N. A., Joseph, G., Shaanker, R. U., and Ganeshaiah, K. N. (2005). Impact of *Lantana camara*, an alien invasive species, on rural livelihoods and communities in south India. In McGarry, D., Shackleton, C. M., Fourie, S., Gambiza, J., Shackleton, S. E., and Fabricius, C. F. (eds). *A Rapid Assessment of the Effects of Invasive Species on Human Livelihoods, Especially of the Rural Poor*. South African National Biodiversity Institute, Kirstenbosch, p. 210.

Kaufmann, J. (2004). Prickly Pear Cactus and Pastoralism in Southwest Madagascar. *Ethnology* 43: 345–361.

Keirungi, J., and Fabricius, C. (2005). Selecting Medicinal Plants for Cultivation at Nqabara on the Eastern Cape Wild Coast, South Africa. *South African Journal of Science* 101: 497–501.

le Maitre, D. C., van Wilgen, B. W., Gelderblom, C. M., Bailey, C., Chapman, R. A., and Nel, J. A. (2002). Invasive alien Trees and Water Resources in South Africa: Case Studies of the Costs and Benefits of Management. *Forest Ecology and Management* 160: 143–159.

Low, A. B., and Rebelo, A. G. (eds) (1996). *Vegetation of South Africa, Lesotho and Swaziland*. DEAT, Pretoria.

McDonald, I. A. W., Kruger, F. J., and Ferrar, A. A. (1986). *The Ecology and Management of Biological Invasions in Southern Africa*. Oxford University Press, Cape Town, p 324.

McGarry, D., Shackleton, C. M., Fourie, S., Gambiza, J., Shackleton, S. E., and Fabricius, C. F. (eds). (2005). *A Rapid Assessment of the Effects of Invasive Species on Human Livelihoods, Especially of the Rural Poor*. South African National Biodiversity Institute, Kirstenbosch, p. 210.

McWilliam, A. (2000). A Plague on your House? Some Impacts of *Chromolaena odorata* on Timorese Livelihoods. *Human Ecology* 28: 451–469.

Mueller-Dombois, D, and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology.* Wiley, Canada, p. 547.

Paumgarten, F. (2005). The Role of Natural Resources as Safety-nets: A Review of Evidence with Emphasis on Southern Africa. *Geojournal* 64: 189–197.

Pimental, D. (2002) (ed.) *Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal and Microbe Species*. CRC, New York. p. 369.

Pimental, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T., and Tsomondo, T. (2000). Economics and Environmental Threats of Alien Plant, Animal and Microbe Invasions. *Agriculture, Ecosystems & Environment* 84: 1–20.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., and West, C. J. (2000). Naturalization and Invasion of Alien Plants: Concepts and Definitions. *Diversity & Distributions* 6: 93–107.

Robertson, M. P., Villet, M. H., Fairbanks, D. H. K., Henderson, L., Higgins, S. I., Hoffman, J. H., le Maitre, D. M., Palmer, A. R., Riggs, I., Shackleton, C. M., and Zimmerman, H. G. (2003). A Proposed Prioritisation System for the Management of Weeds in South Africa. *South African Journal of Science* 99: 37–43.

Rouget, M., Richardson, D. M., Nel, J. L., and van Wilgen, B. W. (2002). Commercially Important Trees as Invasive Aliens—Towards Spatially Explicit Risk Assessment at a National Scale. *Biological Invasions* 4: 397–412.

Scoones, I. (1998). *Sustainable Rural Livelihoods: A Framework for Analysis*. Institute of Development Studies, University of Sussex.

Shackleton, C. M., and Shackleton, S. E. (2004).The Importance of Non-timber Forest Products in Rural Livelihood Security and as Safety-nets: Evidence from South Africa. *South African Journal of Science* 100: 658–664.

Shackleton, C. M., and Shackleton, S. E. (2006). Household Wealth Status and Natural Resource use in the Kat River Valley, South Africa. *Ecological Economics* 57: 306–317.

Shackleton, C. M., Shackleton, S. E., Ntshudu, M., and Ntzebeza, J. (2002). The Role and Value of Savanna Non-timber Forest Products to Rural Households in the Kat River Valley, South Africa. *Journal of Tropical Forest Products* 8: 45–65.

Siges, T. H., Hartemink, A. E., Hebinck, P, and Allen, B. J. (2005). The Invasive Shrub *Piper aduncum* and Rural Livelihoods in the Finschhafen Area of Papua New Guinea. *Human Ecology* 33: 875–893.

van Sittert, L. (2002). Our Irrepressible Fellow-colonist: The Biological Invasion of Prickly Pear (*Opuntia ficus-indica*) in the Eastern Cape c. 1890–c1910. *Journal of Historical Geography* 23: 397–419.

Zimmermann, H. G., and Moran, V. C. (1991). Biological Control of Prickly Pear. *Opuntia ficus-indica* (Cactaceae), in South Africa. *Agriculture, Ecosystems & Environment* 37: 29–35.