An open access e-Journal for sustainable solutions

# Sustainability: Science, Practice, & Policy

**Volume 5 • Issue 2**
**Fall 2009**

**ISSN: 1548-7733**

Journal Editor
**Maurie Cohen** (New Jersey Institute of Technology)

Managing Editor
**Amy Forrester**

## Editorial



## Articles



## Community Essay



## Book Review Perspectives



**Published online • http://ejournal.nbii.org • ejournal@csa.com**

nbii & ProQuest CSA

EDITORIAL

**Nicholas Gray**
Centre for the Environment, Trinity College, University of Dublin

# Using charcoal to fix the price of carbon emissions

While the societal aspiration to become carbon neutral is very laudable it will, unfortunately, be virtually impossible to achieve. Almost everything we do or purchase requires energy derived primarily from fossil fuels that release carbon dioxide ($CO_2$) and other greenhouse gases (GHGs). So it is perverse that increasing numbers of companies, as well as individuals, are currently claiming to be "carbon neutral," yet continue to travel, to heat buildings, and to produce and purchase manufactured goods in much the same way as before this miraculous transformation took place. A major mechanism in achieving apparent carbon neutrality is through offsetting, whereby someone else is paid to eliminate the $CO_2$ you have emitted by investing in carbon-reduction technologies and projects. Air and automobile travel, electricity, gas and oil use, in fact whole business and household GHG footprints, can ostensibly be neutralized by a quick visit to an offsetting company website and the payment of an *appropriate* fee.

Investment in an offsetting project is clearly not eliminating the $CO_2$ contribution to global atmospheric GHGs; at best it is a contribution to reduce the rate of emissions in the future. The most popular option for businesses and individuals alike is tree-planting as this alternative appears to actually turn your $CO_2$ into a fixed carbon product. However, these trees are destined to be harvested and the wood used for fuel or building, or they will eventually fall down and decay. In both cases, almost all of the available carbon taken up by the trees will eventually be released back into the atmosphere as $CO_2$ when the wood is either burned or allowed to decompose. The carbon that has been stored in the forest soil is also very vulnerable to decay with $CO_2$ released when the forest is harvested, replanted or even when environmental conditions, such as temperature, change. The idea that trees can be planted in cycles to maintain offsets is a misconception. Only new forests can offset fresh carbon emissions and these, like any other $CO_2$ sequestering system, must be maintained forever. Therefore, harvested and damaged tress must be replaced to maintain the amount of $CO_2$ originally offset, which means that maintaining this ever increasing forest area is simply not possible on either a national or global scale.

So planting trees as a mechanism of carbon sequestration simply results in a temporary storage of the $CO_2$. As the area of land available for tree-planting is limited, this is clearly neither a realistic nor sustainable option for neutralizing $CO_2$ emissions.

The only certain way to reduce $CO_2$ emissions is to use less fixed carbon fuels and fewer products that employ them either in their manufacture or production, which pretty much includes everything from computers to food. However, in practice, GHG emissions remain well in excess of the required reduction targets, a fact that may in part be due to offsetting. Unfortunately, offsetting allows businesses and individuals to continue to use fixed carbon without any constraint and is widely seen to validate or endorse its continued use at those rates. The attraction of offsetting is that it prevents $CO_2$ from becoming a limiting factor either in business decision making or personal lifestyles. That offsetting enables one to take the moral high ground without any pain has been fully exploited in business GHG footprinting. The companies and organizations that supply offsetting tend to accept its limitations, but believe such arrangements play an important role in supporting low-energy technologies, while both educating and encouraging the public to reduce its $CO_2$ output. In most cases, selling offsets is a company's only source of income, and this feature of the industry makes the offsetting market very competitive and results in a wide variety of charges and charging mechanisms. However, charges are not actually based on any scientific measurement, but merely on what the market is prepared to pay.

Neither a direct carbon tax nor a cap-and-trade scheme will succeed unless a credible price for carbon is set. Making carbon expensive would be an incentive for both carbon reduction and innovation of low-carbon technologies. These aims, however, can only be achieved if carbon prices are both high and stable over the long term so as to stimulate the investment in low-carbon technologies that is urgently

© 2009 Gray

needed. The current European trading price of carbon fluctuates around €12 (US$18.10) per metric ton (1 US ton = 0.907 metric tons). This low market value is a major disincentive for both innovation and reduction activities and will need to be much higher and credible for global warming to be taken seriously within the marketplace. So how do we set the price? What is required is something similar to the gold standard.

Currently, the cost of offsetting is quite arbitrary and is based largely on what the market can sustain. Outside the European Climate Exchange, the leading market for trading $CO_2$ emissions in Europe, prices vary between €2.5 to €10 (US$4 to US$15) per metric ton of $CO_2$ in the United States and United Kingdom respectively, with 75–97% of this sum being spent on offsetting activities depending on whether the provider is a private company or a nongovernmental organization (NGO). The ability to offset $CO_2$ at these extremely low prices is a major disincentive for the adoption of real $CO_2$ reduction policies and actions, which would be far more expensive and inconvenient.

The impact of GHG emissions can presently be reduced only by using less fixed carbon energy or actually removing $CO_2$ from the atmosphere. While there is a great deal of interest in sequestering $CO_2$ by capturing and storing the gaseous emissions from power stations and major manufacturing installations, it is already possible to sequester $CO_2$ through the production and storage of charcoal or biochar. While charcoal is universally used as a fuel, and so the fixed carbon is released as $CO_2$ on combustion, biochar is an innovative method of incorporating the fixed carbon into the soil.

Biochar is finely graded charcoal that is produced solely for use in agriculture using modern pyrolysis technology. When the material is incorporated into the soil, it increases water retention, enhances plant growth by stabilizing the movement of nutrients, and makes the nutrients more biologically available (which reduces fertilizer use). Within the soil environment, biochar is estimated to remain stable for hundreds, and possibly thousands, of years, thus effectively sequestering the $CO_2$. While biochar is extremely promising, its practical use may be limited due to land availability and the relatively small level of application per unit area, as well as concerns about its effects on long-term soil quality and ecology. To date, the possibilities for its use in land reclamation, especially in arid areas, and in the reduction of nitrous oxide and methane released from soils have yet to be fully realized. However, these uses may become its major applications with enhanced environmental benefits in relation to global climate change.

In contrast, the production of charcoal and its long-term storage provides an exciting possibility of large-scale, safe, and relatively cheap carbon sequestration. Unlike other recovery strategies being developed, this method can also provide a real fixed cost for $CO_2$ removal. Commercial charcoal prices vary around the world as do potential production rates, manufacturing methods, and scale of production. Bulk charcoal prices in the United Kingdom range from €310 to €425 (US$466 to US$640) per metric ton giving an average price of €365 (US$553). If we allow €35 (US$53) per metric ton for other costs like forest and production development, storage, and security, €380 (US$572) appears a realistic estimate for the production and long-term storage cost per metric ton of charcoal. As $CO_2$ comprises only 27.3% of carbon by weight, this is equivalent to an offset cost of approximately €104 (US$157) per metric ton of $CO_2$ produced.

Charcoal has a number of key advantages over other sequestering technologies. First, it can be produced and affordably stored with no danger to the environment because it is an extremely stable and nonpolluting material. Second, charcoal provides a low cost solution to sequestration because it requires less energy than its potential alternatives, and it can be reused as a clean fuel when more efficient carbon-sequestration technologies are developed. Finally, the most modern production methods use less valuable timber fractions, thus limiting pollution and using only a small amount of energy (with potential for heat recovery and combined heat and power generation). The challenge is to produce charcoal in a sustainable manner in the volume required.

So what could this mean in practice? It will never be possible to sequester all the carbon produced by industry or the commercial and domestic sectors. However, charcoal provides us with an immediate carbon-sequestration solution that hopefully will become part of a wide portfolio of scientific and technological interventions. Perhaps more importantly, it provides a fixed carbon price that is both economically stable and high enough to act as a real incentive to encourage us to meet our carbon-reduction targets. For example, a round-trip flight from New York to London produces 2.5 metric tons of $CO_2$ (or 4.8 metric tons when radiative forcing is included) and these emissions can be offset when purchasing a ticket for approximately €18 to €35 (US$ 27 to $53) respectively by most companies. Using the charcoal derived cost, the offset would increase to €260 to €499 (US$391 to US$752). This is the reality of our high energy lifestyles and the actual cost of negating the associated emissions.

Using charcoal as a model is probably as close as we can come at present to developing a realistic cost for offsetting $CO_2$ emissions. Of course, carbon taxation needs an equitable basis for calculation and, unlike the current offset costs that are based largely on what the voluntary market can sustain, fixed emission charges per weight may well be the incentive required to achieve elusive GHG reduction targets.

## About the Author

Nicholas Gray (PhD, ScD, C.Biol, FIBiol, FLS, DWM, FTD) is a founding member of the Environmental Sciences Unit (1979), Ireland's first center for postgraduate research and training in environmental science and technology. Renamed the Centre for the Environment in 1998, it acts as a research hub within Trinity College, University of Dublin, and hosts a diverse team of postgraduate and postdoctoral researchers. The Centre has been pivotal in developing environmental policy and management in Ireland, including the establishment of the Environmental Protection Agency. Gray is an internationally known environmental engineer who has worked in water pollution and both water and wastewater treatment for over thirty years. He has written a number of books, most recently *Water Technology* (Elsevier, 2010), *Drinking Water Quality* (Cambridge University Press, 2008), *Biology of Wastewater Treatment* (Imperial College Press, 2005), and over 150 research papers. Apart from wastewater treatment process design and operation, he has been carrying out research for the past two decades on sustainability, and more recently on carbon-footprint analysis. He can be contacted at Centre for the Environment, Trinity College, Dublin 2, Ireland (email: nfgray@tcd.ie**).**

ARTICLE

# Investigation into the sustainability of organic aquaculture of Atlantic cod (*Gadus morhua*)

**Benjamin Birt, Lynda D. Rodwell, & Jonathan P. Richards**
School of Earth, Ocean and Environmental Sciences, University of Plymouth, Portland Square, Drake Circus, Plymouth PL4 8AA UK (email: benbirt2@hotmail.com)

Wild stocks of Atlantic cod (*Gadus morhua*) are low. With fisheries in decline, continued demand for cod has led to a fledgling aquaculture industry and current forecasts call for rapid growth. However, critics blame aquaculture of carnivorous species for further depleting fish stocks and for its wider effects on the marine environment. We examine the activities of Johnson Seafarms, a sea-cage organic cod farming facility in the Shetland Islands, to investigate whether "organic" cod farming can be environmentally, economically, and socially sustainable. Data were collected via public questionnaires and interviews with aquaculture experts. The results show that, before it closed in 2008, Johnson Seafarms was addressing the environmental concerns traditionally associated with aquaculture of carnivorous species and that economic viability is possible as a market exists for organically farmed cod at prices higher than for wild fish. We conclude that organic cod farming, as was practiced in the Shetland Islands, is sustainable on that scale. While the industry has room for measured expansion, overexpansion would increase pressure on natural systems, undermining environmental and, ultimately, social and economic sustainability. Producers and regulators should consider alternative techniques, including land-based or integrated aquaculture systems. Any development should be accompanied by further research regarding the industry's sustainability.

KEYWORDS: marine aquaculture, cages, environmental effects, sustainable use, socioeconomic aspects, organic farming

## Introduction

Global fisheries are in decline, with over two-thirds of marine fisheries fully exploited, overexploited, or depleted (Naylor et al. 1998; 2000; FAO, 2000; 2006; Pauly et al. 2002; Naylor & Burke, 2005; Jacquet & Pauly, 2007).[1] In particular, stocks of Atlantic cod (*Gadus morhua*) are dangerously low across nearly all of the species range that extends across most of the North Atlantic continental shelf, with catches declining significantly in recent years (Myers et al. 1997; Brown et al. 2003; Rosenlund & Skretting, 2006; ICES, 2007).[2] In the North Sea, the eastern part of the English Channel, and the Skagerrak Straight (located between Denmark and Norway), 95% of cod from each year class is caught before the fish have spawned (ICES, 2007).[3] Wild cod populations are unlikely to recover in the next decade, even if the European Commission were to implement more effective management procedures (Horwood et al. 2006) and cod aquaculture is likely to expand as capture fisheries continue to decline (Brown et al. 2003; Lee & Connelly, 2006; Rosenlund & Skretting, 2006).

Environmental concerns though have led to questions about the ultimate sustainability of the aquaculture industry (Pauly et al. 2002; Powell, 2003; Pauly, 2006). While most research focuses on salmonids, the ongrowing stage of sea-cage cod farming (where fish are kept and fed in cages at sea) is nearly identical to that of salmon in terms of techniques, suitable locations, technology, equipment, and husbandry practices, and existing salmon infrastructure can often be used for cod farming (Walden, 2000). In this way, many concerns over salmonid farming are directly relevant to cod operations.

[1] *Fully exploited*: Term used to qualify a stock that is probably neither being overexploited nor underexploited and is producing, on average, close to its maximum sustainable yield.
*Over exploited (Overfished)*: A stock is considered "overfished" when exploited beyond an explicit limit after which its abundance is considered "too low" to ensure safe reproduction.
*Depleted*: A stock driven by fishing to a very low level of abundance compared to historical levels, with dramatically reduced spawning biomass and reproductive capacity. It requires particularly energetic rebuilding strategies and its recovery time will depend on present status, level of protection, and environmental conditions (FAO, 2009).

[2] Atlantic cod is distributed from Cape Hatteras in the southwest, north to Greenland and Iceland, and east to the European coast from the Barents Sea to the Bay of Biscay. The species is encountered at a depth range of 0–600 meters. For further details see http://www.fishbase.org/Summary/SpeciesSummary.php?id=69.

[3] A year class refers to fish spawned (born) in the same season. Cod spawn once a year during winter.

© 2009 Birt et al.

First, the effects of effluent discharge in the form of excessive nutrients from sea-cage farming is a long-standing issue (Folke et al. 1994; Gowen, 1994; Naylor et al. 1998; 2000; Powell, 2003; Goldburg & Naylor, 2004; Naylor & Burke, 2005; Kjesbu et al. 2006). Abnormally high levels of nutrients can alter the structure of benthic (seabed) ecosystems and cause algal blooms that are toxic to fish and shellfish (Anderson et al. 2002).

Second, escaped fish can pose risks if they are significantly different from their wild counterparts either through genetic selection or by being nonnative species (Kapuscinski & Hallerman, 1991; Soto et al. 2001; Naylor et al. 2005). Although cod farming is in its infancy and the effects of escapes are unproven (Dahle et al. 2006), genetically distinct subpopulations of cod exist, so escapes could have negative implications should escaped and wild fish interbreed (Brown et al. 2003; Jørstad, 2004; Bekkevold et al. 2006).

Third, the spread of disease to wild fish can have detrimental effects on the wider ecosystem (Goldburg et al. 2001). For instance, sea lice (*Caligus spp*.) infestations within salmon farms are regarded as responsible for wild fish found with attached sea lice (Naylor et al. 2003). Infestations can prove fatal to fish and early studies indicate that sea lice affect cod (Walden, 2000). As cod farming develops, new diseases are likely to appear (Kjesbu et al. 2006), as indicated by the outbreak of *Francisella* in one cod farm in Norway that saw a 40% mortality rate over a five-month period (Fish Farmer Magazine, 2006).[4]

Finally, reliance on wild-caught fish in aquaculture feed has attracted criticism since aquaculture operations for carnivorous fish can contribute to fishing pressure on certain stocks, such as the Peruvian anchoveta (*Engraulis ringens*) and Chilean jack mackerel (*Trachurus murphyi*) (Naylor et al. 1998; 2000; Pauly et al. 2002; Hannesson, 2003; Powell, 2003; Asche & Tveterås, 2004; Naylor & Burke, 2005; Kjesbu et al. 2006; Opstad et al. 2006).

Despite these concerns, some researchers see Atlantic cod as a promising species for aquaculture (Tilseth, 1990; Aarset et al. 2000) and they predict that cod farming could become a genuine competitor to capture fisheries (Standal & Bouwer Utne, 2007). In Norway, there is a drive to expand cod farming and the European Union (EU) has encouraged diversification of aquaculture into "new species" such as cod (Kaiser & Stead, 2002; Powell, 2003; Dahle et al. 2006; CEC, 2009).

Large-scale production is an objective in Norway, despite concerns about the negative environmental effects of expansive, modern aquaculture operations (Naylor et al. 2000; Pauly et al. 2002). Johnson Seafarms (marketing its cod under the brand name "No Catch") in the Shetland Islands took a different approach based on the notion that cod could be farmed sustainably with minimal negative environmental impact. We investigate this assertion. Although Johnson Seafarms declared bankruptcy in 2008 and was forced to close after incurring unmanageable debts, the environmental and economic principles inherent in the operation remain relevant.

Several recent studies focus on aquaculture's sustainability (see, e.g., Costa-Pierce, 2002; Naylor & Burke, 2005; Dallimore, 2006), but there is a dearth of literature specifically on organic cod farming. Because of the novelty of this activity, research to date on the potential for cod farming in the Shetland Islands has not considered the possibility of environmental impacts or the opportunity to develop organic sea-cage aquaculture systems (Walden, 2000). Johnson Seafarms, the world's first organic cod farm, provides a useful case study to begin to ameliorate this paucity of published work. The idea of a "sustainable management strategy" for cod aquaculture might include criteria that define organic cod farming and set guidelines detailing industry best practices (Dahle et al. 2006). Johnson Seafarms received organic certification from the Organic Food Federation (OFF), having fulfilled the organization's criteria regarding issues such as local environmental impacts, feed ingredients, vaccines and antibiotics, and stocking densities (OFF, 2005).[5] However, other credentialing bodies have their own similar—though competing—guidelines and harmonization of these protocols seems desirable (Hepburn, 2004; OFF, 2005).

This article investigates whether organic cod farming can be environmentally and economically sustainable and poses the question: "Can this practice go on indefinitely in this location?" We also consider the industry with respect to social sustainability. A description of the basics of cod farming is followed by a summary of the research methodology that comprised the collection of quantitative data through closed format questionnaires and qualitative data via interviews with a range of aquaculture experts. We then display and discuss our results and present our conclusions regarding the sustainability of organic cod aquaculture.

[4] Externally, cod infected by *Francisella* exhibit few symptoms other than a reduced appetite and poor swimming. Internally, organs swell and develop white granulation tissue.

[5] The Organic Food Federation (OFF) standards for cod aquaculture have been approved by the Department for Environment, Food and Rural Affairs (DEFRA) in the United Kingdom.

## The Basics of Cod Farming

The process of farming cod can be broken down into three phases: hatchery/nursery in tanks on land, “ongrowing” in sea cages, and processing (slaughtering the fish and preparing them for market). Wild caught fish are kept in tanks on land and used as the broodstock to produce fish for the farm. When they first hatch, young cod spend six to eight days still attached to their yolk-sacs, gradually making the transition to feeding on plankton. After 35 to 40 days, the young cod move to a diet of dry feed and remain in on-land tanks until they reach six to seven months old–and a weight of 20-50 grams. At this stage, they are transferred for ongrowing in sea cages until harvest at around three years of age and 2-5 kilograms (Walden, 2000). As pictured in Figures 1 and 2, sea cages are floating, netted enclosures suspended in the water and anchored to the seabed.

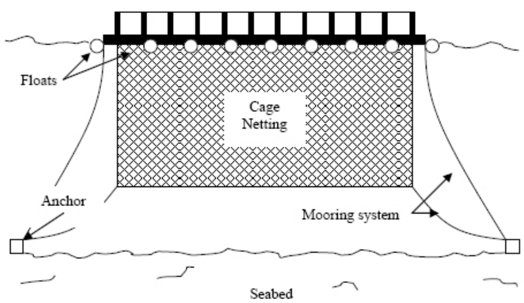


**Figure 1** Key features of a typical sea-cage aquaculture system.

**Figure 2** Sea-cage at Johnson Seafarms (No Catch) cod aquaculture facility, Vidlin, Shetland.

The size, shape, and type of location for the sea cages can vary, but at Johnson Seafarms the cages had a capacity of 2.5 million liters and were located in easily accessible sea lochs with double netting underwater and top netting above the surface to prevent escapes and to guard against predation.

The Johnson Seafarms operation included the hatchery, nursery, ongrowing, and processing stages of the farming process, employing up to 130 people at its peak. The company employed scientists for research and monitoring, technicians and engineers to operate and maintain the cages and other equipment, factory workers to process the fish, and a range of office staff. With almost 30 cages (farming salmon and sea trout as well as cod) in twelve locations, the business produced 2,500 metric tons (mt) of cod in 2007, just prior to bankruptcy. In 2008, the company’s creditors took possession of 3,000 mt of cod, a small amount compared to projected production of 30,000 mt of organic cod by 2012 (10% of the forecasted demand for the United Kingdom). After failing to find a buyer to maintain organic cod production, the creditors closed down the operation and sold the entire business to conventional salmon-farm interests.

## Research Methodology

To assess the potential economic success of organically farmed cod, we administered a public survey to gauge consumer willingness to pay for fish produced under such circumstances. Quantitative data were collected through two closed-format questionnaires. We administered the first survey to twenty customers in each of four fish-and-chip shops in different areas of Plymouth and two in Totnes (southwestern United Kingdom) for a total of 120 respondents. We chose two different geographic areas to achieve a diverse range of survey participants and selected fish-and-chip shops specifically for two reasons. First, we assumed that a high percentage of customers would eat cod and, therefore, provide useful data about their perceptions of the farmed variety. Second, we felt the face-to-face method, where, with the consent of the shop managers, respondents were approached after placing their order, was less intrusive than a street survey while they were eating their meals. We also assumed this approach would generate a higher response rate than other methods (de Vaus, 2002). We administered the second questionnaire to fifteen managers of Plymouth’s fish-and-chip shops to gain cod sellers’ perspectives on selling farmed cod.

We tested the majority of the data collected from both questionnaires for significance using one-sample chi-square tests or chi-square tests for independence, while a Friedman test was used where responses were in the form of rankings. A one-way repeated-measures ANOVA was employed to analyze data from the shop managers regarding cod prices, although the small sample size might have significantly reduced the power of this test.

**Table 1** Interview respondents.

| Respondent | Affiliation/Interest |
|---|---|
| Johnson's Scientist A | Johnson Seafarms Ltd, Shetland |
| Johnson's Scientist B | Johnson Seafarms Ltd, Shetland |
| On-land Aquaculturist | Owner & Operator, Jersey Turbot, land-based aquaculture facility, Jersey, British Isles |
| Scientist A | University of Stirling, Institute of Aquaculture, Marine Environmental Research Laboratory, Scotland |
| Scientist B | School of Biological Sciences, University of Plymouth, UK |
| SEPA Representative | Scottish Environment Protection Agency (SEPA) |
| Conservationist A | Writer and journalist with an interest in aquaculture; formerly with The Salmon Farm Protest Group, UK |
| Conservationist B | Marine Conservation Society, UK |

The research team also collected qualitative data using a series of questions put to a range of aquaculture experts with differing backgrounds and perspectives (Table 1). Although we used a basic set of questions, respondents were encouraged to expand upon their answers if they saw fit to do so. For this reason, the interview technique can be described as either semistructured or unstructured. We employed a thematic "framework" analysis to sort and analyze the data, taking care not to lose sight of the original context when removing sections of text from the full transcripts (see Ritchie & Spencer, 1994).

## Results

We tested the data generated by the responses to each section of both questionnaires for statistical significance. Based on the surveys, it is not possible to identify any correlation between consumers' knowledge of environmental, ethical, or sustainability issues concerning cod and their behavior when choosing a particular type of cod. The results of a one-sample chi-square test for statistical significance were inconclusive ($\chi^2$=0.03, p=0.86), the data showing a near 50-50 split (59 aware, 61 not aware) of how many respondents were familiar with such issues (Table 2).

A one-sample chi-square test showed a high level of significance ($\chi^2$=77.89, p≤0.05), suggesting that very few people in the target population inquired about the origin of the cod that they ate (Table 2). This finding suggests that farmed and/or organically farmed cod may have a market regardless of consumer opinion. In other words, as many people did not know where their fish came from, they would be likely to eat farmed cod without knowing it.

We used a chi-square test for independence to determine whether awareness of farmed cod was independent of awareness of the organically farmed variety. Knowledge of the existence of farmed cod was significantly higher than organically farmed cod ($\chi^2$=15.65, p≤0.05), about which only nine respondents had any familiarity. This result shows the need for more public education if farmed, and particularly organically produced, cod is to become widely recognized by consumers.

Results of one-sample chi-square tests ($\chi^2$=34.35 and 38.15, p≤0.05) were shown to be statistically significant in that a high percentage of people would consider eating both farmed and organically farmed cod (Table 2). A chi-square test for independence ($\chi^2$=229.55, p≤0.05) showed that those who would eat farmed cod are also more likely to eat organically farmed cod.

A one-sample chi-square test ($\chi^2$=86.56, p≤ 0.05) showed only a small minority (5/120) of respondents to oppose a fish farm in their local area (Table 2). Although the south of England may be unsuitable for cod farming, this result hints that expansion of cod

**Table 2** Public questionnaire: summary of questions and results.

| Question | N | Yes | No | Maybe | Mean | Standard Deviation | $\chi^2$ | Significance (p) |
|---|---|---|---|---|---|---|---|---|
| Are you aware of any environmental, ethical, or sustainability issues concerning cod? | 120 | 59 | 61 | – | 1.51 | 0.502 | 0.03 | 0.86 |
| Do you check which geographical area your cod comes from? | 104 | 7 | 97 | – | 1.93 | 0.252 | 77.89 | 0.00 |
| Are you aware of the existence of farmed cod? | 120 | 46 | 74 | – | 1.62 | 0.488 | 6.53 | 0.01 |
| Are you aware of the existence of organically farmed cod? | 120 | 9 | 111 | – | 1.93 | 0.264 | 86.70 | 0.00 |
| Would you eat farmed cod? | 120 | 69 | 18 | 33 | 1.58 | 0.741 | 34.35 | 0.00 |
| Would you eat organically farmed cod? | 120 | 71 | 18 | 31 | 1.56 | 0.742 | 38.15 | 0.00 |
| Would you be happy for fish farming to exist in your area? | 120 | 86 | 5 | 29 | 1.33 | 0.552 | 86.55 | 0.00 |

**Table 3** Shop manager questionnaire: Would shop-managers sell farmed/organically farmed cod?

| Question | N | Yes | No | Maybe | Mean | Standard Deviation | $\chi^2$ | Significance (p) |
|---|---|---|---|---|---|---|---|---|
| Would you sell farmed cod? | 15 | 4 | 2 | 9 | 1.87 | 0.640 | 5.20 | 0.07 |
| Would you sell organically farmed cod? | 15 | 4 | 2 | 9 | 1.87 | 0.640 | 5.20 | 0.07 |

farming might not run contrary to public opinion. More research, however, would be needed in appropriate locations before drawing conclusions on this point.

Only two of the fifteen shop-manager respondents would not serve farmed or organically farmed cod. While a chi-square test for independence proved significant ($\chi^2$=16.16, p≤0.05), two one-sample chi-square tests (both $\chi^2$=5.20, p=0.07) were not statistically significant. The data here show a majority (nine respondents) answered "maybe" to this question, citing customer opinion as the factor that would determine their fish-selling policy (Table 3).

A Friedman test to investigate the consistency of responses suggests significant differences between how much people were willing to pay for the three types of cod (wild cod from a sustainable capture fishery, conventionally farmed cod, and organically farmed cod) compared to standard wild cod ($\chi^2$=94.43, p≤0.05). Respondents were willing to pay a mean premium of up to 50 pence (US$0.82) for an average sized portion of cod (150 grams) from a sustainable capture fishery above that for a similar meal prepared from standard wild fish and a premium of up to 25 pence (US$0.41) for organically farmed cod. Farmed cod was the least popular with consumers, who were willing to pay 25 pence less (Table 4).

A one-way repeated-measures ANOVA test looked for differences between respondents. The test provided no statistically significant information on the prices that shop managers were willing to pay for the three types of cod (F=2.35, p=0.14) (Table 4). Wholesale prices for cod fluctuate greatly, as the supply levels are not always guaranteed due to changeable weather and fish abundance, and it proved difficult for respondents to provide meaningful specific figures. In addition, the shop managers were keen to demonstrate the importance of customer opinion in influencing the type of fish they sold as well as its price, implying that an important driver for any future farmed cod market will be the customers. It should be noted that the small sample size might have reduced the power of the ANOVA test in this case.

## Discussion

With consumer demand for cod set at current levels, it seems unlikely that farming can entirely replace wild fisheries purely in terms of production volume. Even though Norway has the potential to produce over 500,000 mt of cod per year from aquaculture (Adoff et al. 2002), Scientist B reminded us that in the United Kingdom the scope for expansion is limited, with cod farming only practical in colder waters such as Scotland and its islands. On the other hand, the amount of adaptation of existing infrastructure required to convert a salmon farm into a cod farm is minimal. Whether the switch from salmon to cod will occur is not yet clear, but Conservationist A sees it as a distinct possibility and notes that "because of the [negative] reputation that salmon farming has

**Table 4** Prices willing to be paid for three types of cod by customers and shop managers.

| Question | N | Farmed cod | | Organically farmed cod | | Cod from a sustainable capture fishery | | Statistical test |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation | |
| How much would you be willing to pay for the following types of cod and chips? (Customer) | 102 | Up to 25p less than currently | 1.32 | Up to 25p more than currently | 1.49 | Up to 50p more than currently | 1.17 | Friedman $\chi^2$=94.43, p=0.00 |
| How much would you be willing to pay per pound for the following types of cod? (Manager) | 13 | £2.50 | 24.50 | £2.61 | 34.60 | £2.51 | 25.34 | ANOVA F=2.35, p=0.14 |

garnered for itself, a lot of the salmon farmers would be very happy to change to cod." One possible barrier to an expansion of cod farming through a switch from salmon farming, pointed out by Conservationist B, is climate change and the anticipated rise in water temperatures. This will further shrink the area conducive to farming cod.

For Scientist A, "any expansion comes down to basic economics–you have to make money doing it," and although the Scottish Environment Protection Agency (SEPA) representative believes that "in the medium to long term, it is possible that farmed cod will replace caught fish," the need to establish economic success is essential if the industry is to create a platform on which to grow. In its early stages, Johnson Seafarms appeared to be a prime example of potential economic viability in the present market. Although cautious in being too quick to claim economic success, Johnson Seafarms Scientist A comments that the company did not "need to be hitting the same market as wild fisheries" as its product was "driven towards the high end of the market," summing up well the economic intentions of the Shetland Islands' only cod farm. Support for the economic viability of niche-market aquaculture also comes from the SEPA representative, the on-land aquaculturist (who has successfully exploited a niche in his local seafood market), and the two scientist respondents.

In addition, the survey data demonstrate that organically farmed cod consistently ranks higher than farmed cod in popularity and imply that shop managers would base their decisions about what type of fish to sell on customer opinion (Table 4). The willingness of respondents to pay more for organically farmed cod and the lack of opposition to local cod farms (a purely hypothetical concept due to climatic constraints) both give credence to the idea of successful niche markets.

The eventual failure of Johnson Seafarms' No Catch venture weakens the argument for economic sustainability based on niche markets. However, the demise of one operation does not undermine the workability of the general concept. Several factors were involved in the company's ultimate closure. First, the organic status of the cod facilities meant higher overall operating costs. Feed costs were between 15 and 20% higher than for a conventional cod farm and the organic certification required lower stocking densities (Fish Farmer Magazine, 2008). In addition, the bankruptcy administrators point to an ongoing battle to increase the knowledge of growth curves for cod, decrease mortality rates, and lower production costs (Fish Farmer Magazine, 2008).

However, based on the experiences of organic operations for other species such as salmon, Johnson Seafarms' management would have been able to anticipate many, if not all, of these costs so they do not, on their own, explain the ultimate collapse. A key factor in the dissolution of the company was the global credit crunch and resulting financial crisis, with the principal creditor, the Icelandic bank Kaupthing, calling in loans in February 2008, just before an economically important harvest was ready (Carrell, 2008; Clover, 2008).[6] The lack of a preexisting model on which to make financial or business forecasts is also likely to have played a part. Johnson Seafarms seems to have suffered for being a market innovator.

Despite the company's eventual closure, managers and bankruptcy administrators alike remain confident that organic, sustainable cod farming can be successful (Carrell, 2008; Clover, 2008). Future organic farms will have to contend with higher production costs than conventional operations, but Johnson Seafarms demonstrated that consumers were willing to pay a premium for their product that was approximately 50% higher than the price for wild cod.[7] In addition, technological advances that the company made will benefit future cod operators. It seems likely that, given a more favorable economic climate and with careful management and solid financial backing, future organic operations could achieve extended success.

Experience with salmon farming shows that employment levels on fish farms can significantly decline over time as efficiency increases. Figures from the Scottish Executive (2006) show that between 1995 and 2005, Scotland's farmed salmon production rose from 70,060 to 129,588 mt, while the number of staff employed in production dropped from 1,355 to 979 people. Although a highly mechanized and efficient farming system could conceivably be economically and environmentally sustainable, the resulting social effects may be untenable.

However, Johnson Seafarms started positively in terms its recruitment of staff, increasing from about 30 to over 100 employees before the company went into bankruptcy (Johnson Seafarms Scientist B). If a future operation were able to maintain relatively high employment figures, the employment benefits to local communities would be significant, meaning social sustainability may well be attainable. This might be more achievable if organic cod aquaculture were

6 The timing of this intervention provides insight into the bank's precarious financial situation (Cherry, 2009). Specifically, the Icelandic government assumed ownership of Kaupthing and the bank filed for bankruptcy in the United States mere months later (Reuters, 2008).

7 This premium is similar to that received by organically farmed salmon with Irish organic salmon, for example, fetching 40% over the market price for conventionally farmed salmon (Fish Farmer Magazine, 2009).

practiced on a "smaller unit basis rather than by vast corporations" (Scientist B). Scientist B's reasoning stems from the tendency for the drive for greater efficiency in large-scale operations to substitute mechanical alternatives for human labor wherever feasible. Automated systems can largely replace the need for employees for tasks such as monitoring of water conditions and feeding fish.

Several environmental issues associated with sea-cage aquaculture, and the ways in which Johnson Seafarms was addressing them, merit discussion. Due to high fish densities in relatively small areas, disease outbreaks are a significant threat in sea-cage aquaculture.[8] While disease is "not a major problem so far…it is [in its] early days and no doubt it will get worse" (Scientist A). Marine Harvest, with its head office in Norway, is one of the world's major multinational aquaculture companies and the firm has interests in a number of fish species. It lost a large proportion of its cod stocks in 2005 to a newly observed disease, *Francisella* (Olsen et al. 2006).[9] Such an episode would have been economically disastrous for Johnson Seafarms because of its reliance on heavy outside investment. The economic implications of a serious outbreak of an untreatable disease are clear. Of concern to the wider environment is the possibility of wild fish contracting diseases by swimming near sea-cages containing infected farmed fish. Again, we see the intrinsic link between environmental and economic health and sustainability. As the industry expands, it will need to place greater effort on sharing information and products (particularly vaccines) between Norway and the United Kingdom. Unfortunately, at present, given that cod aquaculture is a relatively new industry in Europe, regulations do not facilitate this process (Scientist A), leading to concern that potentially avoidable disease outbreaks will occur in the future.[10]

The broodstock used in the organic cod farm in the Shetland Islands was taken from the wild. Therefore, should fish escape, "what [they would] impart genetically on wild stocks wouldn't be a problem" (Johnson Seafarms Scientist A). However, it appears that with well-maintained double-netting systems, such as those used by Johnson Seafarms, escapes can be minimized, or even eliminated. Nonetheless, in terms of possible industry expansion, regulators must take care, for cod, as a species, is more prone to pick away at the nets than salmon (Conservationist B; Johnson Seafarms Scientist A). If future operations sought to reduce their expenses by using single-net systems, escapes would be more likely. If this scenario were combined with a genetic selection program, where fish were bred to grow quickly in sea cages rather than for life in the wild, questions over sustainability would arise as any mixing might weaken the genetic strength of wild cod populations.

Another contentious subject has been the constant artificial lighting used to prevent sexual maturation in farmed cod by inhibiting the onset of puberty. Such equipment enables operators to reduce mortality and to ensure that more of the food energy given to the fish is converted into flesh. Proponents of the system argue that constant light is beneficial to the welfare of the fish as it prevents maturation–a highly stressful time for fish and a time of significant mortality (Conservationist B; Scientist A; Johnson Seafarms Scientist A). The Organic Food Federation, the organization that granted Johnson Seafarms its organic status, accepts this side of the welfare argument. Opponents of artificial lighting, however, assert that "fish do not naturally live in perpetual light" (Conservationist A). The Soil Association agrees and refused to grant organic status to Johnson Seafarms, commenting that constant artificial lighting is not compatible with its vision of what is organic as it strays too far from the animals' natural environmental conditions (Poulter, 2007).[11] While we set aside the specific question of fish welfare, energy use is the issue for sustainability that we consider here. Significant electricity is required and research is ongoing to develop low energy forms of light and to experiment with different lighting regimes (Migaud, 2007; Conservationist B).

Loss of fish to predation has long been a problem for sea-cage farmers. The traditional solution to the problem has been to shoot the predators (Scientist B), grey seals in the case of cod. At present, grey seals are not endangered in waters surrounding the United Kingdom, but destroying those parts of the natural setting deemed unhelpful by humans cannot be considered sustainable and seals are a vitally important part of the marine ecosystem (Österblom et al. 2007). Once again, though, Johnson Seafarms had carefully thought-out policies, employing a highly visible top-netting system to deter seabirds and an underwater taut double-netting system to keep out

[8] See Samuelsen et al. (2006) for a detailed review of the diseases associated with Atlantic cod and their treatments.

[9] The disease was previously unobserved due to the relatively short history of cod aquaculture. There is no efficient treatment or vaccine at this stage.

[10] The imperfect situation regarding vaccine sharing is a symptom of a relatively young industry in which regulations have struggled to keep pace with vaccine developments. Furthermore, there is little pressure at present to resolve matters as the European Union's cod production levels are minimal compared to Norway's.

[11] Artificial lighting undoubtedly prevents maturation in cod and therefore reduces mortality. The Soil Association's refusal to grant organic status essentially hinged on the welfare issue of subjecting fish to 24-hour lighting and on the concept of manipulating their natural life stages.

seals. While these measures entailed added expense and were more time-consuming than traditional, looser, and less visible netting systems that can entangle seals and birds, they had no ill effect on would-be predators and enhanced the company's claims to be environmentally forward thinking. Furthermore, the all-important goal of protecting the fish from predators was achieved.

One of the principal barriers to the sustainability of carnivorous aquaculture has been that "to feed the carnivores, fishermen are fishing for fish to feed to fish" (Ellis, 2003). The feed issue is a significant challenge in that many of the fish caught for aquaculture feed could be consumed directly by humans, particularly in developing nations, rather than used for farmed fish that are often expensive luxuries. Various solutions have been suggested, including vegetable protein as a partial or full replacement for fish protein (Scientist A), but increasing competition for space and resources on land might prove problematic (Scientist B; Johnson Seafarms Scientist A). An option favored by Conservationist B and Scientist B is the use of porcine blood meal, although consumer acceptance is uncertain (Johnson Seafarms Scientist B; Conservationist B).

Johnson Seafarms sourced feed from offcuts from herring and mackerel fisheries. Although this put them in some competition with fertilizer and pet food manufacturers, on the face of it, it is difficult to argue that this practice is unsustainable, as it placed no new pressure on resources. However, one issue might still block the company's claims to have produced the world's first sustainably farmed cod, while a second issue could affect the sustainability of future operations.

First, are the herring and mackerel fisheries from which Johnson Seafarms sourced its offcuts sustainable in their own right? In the absence of an independent certification, it cannot be said with confidence that they are sustainable. However, two policies show that the company was moving in the right direction in this area. An initial strategy was a gesture of sourcing from offcuts at all when it would have been significantly cheaper to use fisheries targeting their catch specifically for aquaculture (Johnson Seafarms Scientist B; Conservationist B). A subsequent policy encouraged the Marine Stewardship Council (MSC) to investigate certifying the pelagic fishery from which the company obtained its offcuts (Johnson Seafarms Scientist A).

The second issue regarding sustainability centers on expansion. Given the operating size of Johnson Seafarms, the level of the organic cod-farming industry's demands on natural capital may well have qualified it for sustainable status but, should future operations prove economically successful, other producers will be tempted to enter the market. Competition for offcuts would increase and new producers might not meet the exacting environmental standards that Johnson Seafarms set for itself (Conservationist B).

Despite these two caveats, Conservationist A feels that MSC certification of feed fisheries would be a significant step toward sustainability, although he does pose the question of who should police the fishery prior to and after such a determination is made. As a result of his years campaigning against the salmon-farming industry, Conservationist A is the first to admit that he has a trust issue. However, he says, "It's the best we've got just now" and the feed issue is a complex one that lacks one single solution (Conservationist B).

Pollution discharges from fish farms can moreover be cause for environmental concern. "Any aquaculture operation is going to have a footprint" (Johnson Seafarms Scientist A). "If you stop for a period of time, the ecosystem should be able to get back to how it was before–that's the test" (Johnson Seafarms Scientist B). These two comments indicate Johnson Seafarms' realistic attitude toward pollution discharges. However, comments from Conservationist A about "the amount of pollution that emanates from Scotland's West Highlands and Islands fish farms," estimating that "the discharges are equivalent roughly to a population of 10 million people," are cause for concern. A WWF report quantified the nitrogen pollution as being equivalent to the annual sewage discharges of a population of 3.2 million people, while phosphorous discharges were comparable to those of 9.4 million people (MacGarvin, 2000). The fish-farming industry clearly contributes some pollution to the marine environment, but the regulators claim to have taken a more precautionary approach with cod-stocking densities than with other species by limiting the biomass to 66% of what would be allowed for salmon (Conservationist B; SEPA Representative). The precautionary stocking density appears appropriate given that surveys have shown that the effects of cage discharges from the Shetland site on the seabed were measurable and, although not considered excessive when compared to other species, increased over a three-year period (Cromey et al. 2009).

Although it is difficult to separate cod and salmon farming, as they are part of the larger fish-farming industry, and while taking care not to view cod farming in isolation, discharges from cod farms appear to be lower than from salmon farms. Cod feces are less solid than salmon feces and therefore disperse more easily, thereby reducing the impact on the local environment (Johnson Seafarms Scientists A & B; Scientist A; Conservationist B). Furthermore, with careful feeding regimes, waste feed can be minimized (as it can with all species), something that

Johnson Seafarms Scientist A says "is not only driven out of an ethical concern, but also an economic one–we don't want to be wasting feed." This observation again demonstrates the direct link between environmental and economic sustainability.

More research is required regarding local environmental damage from the cod-farming operation in the Shetland Islands. However, the annual benthic surveys mandated by legislation have shown that the areas under the cages are still populated by several species that are known bioindicators of ecosystem health, although there was a measurable impact from the operation over a three-year period (Cromey et al. 2009; Johnson Seafarms Scientist A). Although nutrient loading and the potential for resulting algal blooms is harder to quantify (and even more difficult to pin down to a specific aquaculture facility) (Folke et al. 1994; Black et al. 1997), the low level of local damage caused by discharges is a promising sign.

### *Alternative Aquaculture Techniques*

At Jersey Turbot, a facility located on the island of Jersey that grows a species of flatfish, turbot (*Psetta maxima*), in tanks on land, testing of water quality by the Department of Environment, Food, and Rural Affairs (DEFRA) has shown pollution to be "absolutely negligible."[12] This situation would no doubt come as welcome news to one of cage-based fish farming's most vocal critics, Conservationist A, who commented, "My basis for supporting aquaculture is very simple. Do it on land–land-based, closed-containment systems." There are reasons for concern. Sea farming in an open system is more prone to outbreaks of disease (Scientist B) while closed, land-based systems are less at risk because contact with wild fish is nonexistent (On-land Aquaculturist).

The environmental advantages of land-based recirculation aquaculture systems are described by Rawlinson & Forster (2000) who also show that it can be economically viable on several different scales. However, Johnson Seafarms Scientist A questions the economic viability of land-based aquaculture for cod, citing problems of space and energy use in pumping water. His conclusion: "Indeed, it would be possible, but does it make economic sense?" is in line with the Scottish Executive's summary of the situation (Highlands & Islands Enterprise, 2002). It would appear, therefore, that as long as legislation allows fish farms to be located in the sea, aquaculture producers will favor cage systems.

Scientist B referred to the Blue Water Flatfish project in Anglesey, North Wales, a land-based facility that has taken the step of growing reeds and polychaete worms in the enriched sediment created by the farm's discharges. Such integrated systems may provide an opportunity for reducing pollution discharges to near zero and research has highlighted the potential of both land-based and sea-based integrated systems (Chopin et al. 2001; Troell et al. 2003; Neori et al. 2004). In addition, the Scottish Executive has shown an interest in combining finfish farming with seaweed or shellfish production (Highlands & Islands Enterprise, 2002). The environmental benefits associated with such systems include their ability to control and reduce pollution discharges associated with fish farms (Wurts, 2000; Frankic & Hershner, 2003), resulting in a shift toward sustainability. Furthermore, Neori et al. (2004) assure us that there can also be economic benefits in the form of high profitability–clearly a vital consideration when assessing the industry's sustainability from a comprehensive perspective.

### *Regulations Present and Future and Their Implications*

Johnson Seafarms Scientist A, Conservationist A, and Scientist B alluded to the heavy nature of the regulatory framework. Indisputably, the industry is subject to considerable oversight, but it is equally certain that some areas are in need of improvement. Two suggestions are of particular interest.

First, Conservationist A has called for an independent regulatory body for all forms of aquaculture. While arguments might develop over exactly what constitutes an independent regulatory body, and some might say it already exists, an outside authority is desirable to achieve and to maintain sustainability. Second, Scientist B reminds us that the very words "sustainability" and "organic" have yet to be clearly defined in a widely accepted way. As he puts it, "Lots of people have jumped on the bandwagon." However, without legally recognized definitions, spurious claims might serve to undermine operators that are truly achieving sustainable production.

## Conclusion

Cod aquaculture relies heavily on functioning ecosystems. The feed supply depends on viable wild fish populations and the cage systems require clean coastal waters. Economic sustainability, in the form of consumer demand, and environmental sustainability are intrinsically linked. This study has demonstrated that a market for fish produced in an environmentally sensitive manner exists in the United Kingdom. The ease with which Johnson Seafarms sold its fish to retailers at premium prices adds weight to this argument and is an encouraging sign for the future of

[12] Jersey Turbot is operated by one of the respondents for this study, who is identified as "On-Land Aquaculturist."

this incipient industry. Less promising is the failure of the company to sustain itself. The demise occurred for several reasons, including the high costs associated with farming a "new" species organically; the fact that, as the first operation of its kind, no model existed to build on; and the unfortunate timing of the global financial crisis. However, this demise does not automatically mean that environmentally sustainable aquaculture is destined to fail socially and economically. Well-managed future operations in a more favorable economic climate still have the potential to succeed.

With the industry represented by a sole producer, this investigation clearly has limited scope. However, a benchmark now exists from which to conduct further inquiries. Johnson Seafarms was tackling the serious obstacles to environmental sustainability, namely pollution, escapes, disease, and feed. If the methods and operational size that they demonstrated are used again in the future, organic cod farming may very well be able to show itself as environmentally, economically, and socially sustainable.

Given current sea-cage infrastructure and feed-production technologies, any expansion of the industry will inevitably result in increased pressure on the local environment and wider natural resource base in the form of fish for feed (at least until alternative feed sources can be more broadly commercialized). However, measured expansion can be sustainable as long as it replicates and seeks to improve upon Johnson Seafarms' effective practices.

Nonetheless, organic cod farming cannot be viewed in isolation. Given the experiences of Johnson Seafarms, and the economic risks, any expansion of cod aquaculture is likely to include conventional, nonorganic methods that are likely to have a greater impact on the environment. Little is to be gained by the sustainability of only one section of the industry. Beyond defining organic and sustainable aquaculture standards, regulators have a duty to encourage best practices in all forms of aquaculture.

## Acknowledgement

We would like to thank the eight aquaculture experts (Table 1) for their time and valuable input. We would also like to thank the two anonymous reviewers and the journal editor, Maurie Cohen, for their comments and suggestions on earlier versions of the manuscript.

## References

Aarset, B., Standal, D., & Asche F. 2000. *Cod Farming at the Intersection of Fisheries and Aquaculture*. Working Paper No. 70/00. Bergen, Norway: Foundation for Research in Economics and Business Administration. http://bora.nhh.no/bitstream/2330/1318/1/A70_00.pdf.

Adoff, G., Skjennum, F., & Engelsen, R. 2002. Experience and prospects of Norwegian cod farming. *Bulletin of the Aquaculture Association of Canada* 102(1):8–11.

Anderson, D., Glibert, P., & Burkholder, J. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. *Estuaries and Coasts* 25(4):704–726.

Asche, F. & Tveterås, S. 2004. On the relationship between aquaculture and reduction fisheries. *Journal of Agricultural Economics* 55(2):245–265.

Bekkevold, D., Hansen, M., & Nielsen, E. 2006. Genetic impact of gadoid culture on wild fish populations: predictions, lessons from salmonids and possibilities for minimizing adverse effects. *ICES Journal of Marine Science* 63(2):198–208.

Black, E., Gowen, R., Rosenthal, H., Roth, E., Stechy, D., & Taylor, F. 1997. The costs of eutrophication from salmon farming: implications for policy–a comment. *Journal of Environmental Management* 50(1):105–109.

Brown, J., Minkoff, G., & Puvanendran, V. 2003. Larviculture of Atlantic cod (*Gadus morhua*): progress, protocols and problems. *Aquaculture* 227(1–4):357–372.

Carrell, S. 2008. World's First Organic Cod Farm Sinks into Administration With £40 Million Debt. http://www.guardian.co.uk/environment/2008/mar/06/environment.ethicalfishing. December 1, 2008.

Cherry, D. 2009. Another one bites the dust. *IntraFish* February 20.

Chopin, T., Buschmann, A., Halling, C., Troell, M., Kautsky, N., Neori, A., Kraerner, G., Zertuche-González, J., Yarish, C., & Neefus, C. 2001. Integrating seaweeds into marine aquaculture systems: a key toward sustainability. *Journal of Phycology* 37(6):975–986.

Clover, C. 2008. World's First Organic Cod Farm Closes. http://www.telegraph.co.uk/earth/earthcomment/charlesclover/3339185/Worlds-first-organic-cod-farm-closes.html. December 1, 2008.

Commission of the European Communities (CEC). 2009. *Communication from the Commission to the European Parliament and the Council: Building a Sustainable Future for Aquaculture.* Brussels: CEC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0162:FIN:EN:PDF.

Costa-Pierce, B. 2002. Ecology as the paradigm for the future of aquaculture. In B. Costa-Pierce (Ed.), *Ecological Aquaculture: the Evolution of the Blue Revolution*. pp. 339–372. Malden, MA: Blackwell.

Cromey, C., Nickell, T., Treasurer, J., Black, K., & Inall, M. 2009. Modelling the impact of cod (*Gadus morhua* L.) farming in the marine environment–CODMOD. *Aquaculture* 289(1–2):42–53.

Dahle, G., Jørstad, K., Rusaas, H., & Otterå, H. 2006. Genetic characteristics of broodstock collected from four Norwegian coastal cod (*Gadus morhua*) populations. *ICES Journal of Marine Science* 63(2):209–215.

Dallimore, J. 2006. Consumers drive consensus on sustainability. *Fish Farming International* 33(1):39.

de Vaus, D. 2002. *Surveys in Social Research.* 5th ed. New York: Routledge.

Ellis, R. 2003. *The Empty Ocean*. Washington, DC: Island Press.

Fish Farmer Magazine. 2006. New cod disease found in Norway. December 15:34.

Fish Farmer Magazine. 2008. Scottish Sea Farms and Hjaltland Buy No Catch Sea Farming Sites. http://www.fishfarmer-magazine.com/news/fullstory.php/aid/1587/Scottish_Sea_Farms_and_Hjaltland_buy_No_Catch_sea_farming_sites.html. December 1, 2008.

Fish Farmer Magazine. 2009. Scope for expansion of Irish organic salmon. http://www.fishfarmer-magazine.com/news/fullstory.php/aid/1817/Scope_for_expansion_of_Irish_organic_salmon.html. May 8, 2009.

Food and Agriculture Organization of the United Nations (FAO). 2000. *The State of World Fisheries and Aquaculture 2000*. Rome: FAO.

Food and Agriculture Organization of the United Nations (FAO). 2006. *The State of World Fisheries and Aquaculture 2006*. Rome: FAO.

Food and Agriculture Organization of the United Nations (FAO). 2009. *Fisheries Glossary*. http://www.fao.org/fi/glossary/default.asp. May 8, 2009.
Folke, C., Kautsky, N., & Troell, M. 1994. The costs of eutrophication from salmon farming: implications for policy. *Journal of Environmental Management* 40(2):173–182.
Frankic, A. & Hershner, C. 2003. Sustainable aquaculture: developing the promise of aquaculture. *Aquaculture International* 11(6):517–530.
Goldburg, R., Elliott, M., & Naylor, R. 2001. *Marine aquaculture in the United States*. Washington, DC: Pew Oceans Commission.
Goldburg, R. & Naylor, R. 2004. Future seascapes, fishing, and fish farming. *Frontiers in Ecology and the Environment* 3(1):21–28.
Gowen, R. 1994. Managing eutrophication associated with aquaculture development. *Journal of Applied Ichthyology* 10(4):242–257.
Hannesson, R. 2003. Aquaculture and fisheries. *Marine Policy* 27(2):169–178.
Hepburn, J. 2004. Organic aquaculture–the UK experience. *INFOFISH International* 4:14–18.
Highlands & Islands Enterprise. 2002. Scottish Executive Review of the Aquaculture Industry in Scotland. http://www.scotland.gov.uk/Resource/Doc/46951/0024232.pdf. December 1, 2008.
Horwood, J., O'Brien, C., & Darby, C. 2006. North Sea cod recovery? *ICES Journal of Marine Science* 63(6):961–968.
International Council for the Exploration of the Sea (ICES). 2007. *ICES Advice 2007, Book 6: North Sea.* Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems. Copenhagen: ICES. http://www.ices.dk/products/icesadvice/2007/ICES%20ADVICE%202007%20Book%206.pdf.
Jacquet, J. & Pauly, D. 2007. The rise of seafood awareness campaigns in an era of collapsing fisheries. *Marine Policy* 31(3):308–313.
Jørstad, K. 2004. Genetic studies in marine stock enhancement in Norway. In K. Leber, S. Kitada, H. Blankenship, & T. Svåsand (Eds.), *Proceedings of Second International Symposium on Stock Enhancement and Sea Ranching*. pp. 339–352. Malden, MA: Blackwell Science.
Kaiser, M. & Stead, S. 2002. Uncertainties and values in European aquaculture: communication, management and policy issues in times of "changing public perceptions." *Aquaculture International* 10(6):469–490.
Kapuscinski, A. & Hallerman, E. 1991. Implications of introduction of transgenic fish into natural ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences* 48(1):99–107.
Kjesbu, O., Taranger, G., & Trippel, E. 2006. Gadoid mariculture: development and future challenges. Introduction. *ICES Journal of Marine Science* 63(2):187–191.
Lee, D. & Connelly, J. 2006. Global aquaculture alliance on best aquaculture practices: an industry prepares for sustainable growth. *Sustainable Development Law & Policy* 7(1):60–62.
MacGarvin, M. 2000. *Scotland's Secret? Aquaculture, Nutrient Pollution Eutrophication and Toxic Blooms*. Modus Vivendi for WWF. Glenlivet, Scotland: WWF Scotland. http://www.wwf.org.uk/filelibrary/pdf/secret.pdf.
Migaud, H. 2007. Development of new management strategies for cod mariculture. *Aquaculture News* 33:12–13.
Myers, R., Hutchings, J., & Barrowman, N. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. *Ecological Applications* 7(1):91–106.
Naylor, R., Goldburg, R., Mooney, H., Beveridge, M., Clay, J., Folke, C., Kautsky, N., Lubchenco, J., Primavera, J., & Williams, M. 1998. Nature's subsidies to shrimp and salmon farming. *Science* 282(5390):883–884.
Naylor, R., Goldburg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, J., Folke, C., Lubchenco, J., Mooney, H., & Troell, M. 2000. Effect of aquaculture on world fish supplies. *Nature* 405(6790):1017–1024.
Naylor, R., Eagle, J., & Smith, W. 2003. Salmon aquaculture in the Pacific Northwest: a global industry with local impacts. *Environment* 45(8):18–39.
Naylor, R. & Burke, M. 2005. Aquaculture and ocean resources: raising tigers of the sea. *Annual Review of Environment and Resources* 30:185–218.
Naylor, R., Hindar, K., Fleming, I., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D., & Mangel, M. 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *BioScience* 55(5):427–437.
Neori, A., Chopin, T., Troell, M., Buschmann, A., Kraemer, G., Halling, C., Shpigel, M., & Yarish, C. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture* 231(1–4):361–391.
Organic Food Federation (OFF). 2005. Aquaculture Standards. Book 7: Gadoids. http://www.orgfoodfed.com/Our%20Standards.htm. May 8, 2009.
Olsen, A-B., Mikalsen, J., & Colquhoun, D. 2006. New disease identified in Norway's farmed cod. *Aquaculture Health International* 4:7.
Opstad, I., Suontama, J., Langmyhr, E., & Olsen, R. 2006. Growth, survival, and development of Atlantic cod (*Gadus morhua L.*) weaned onto diets containing various sources of marine protein. *ICES Journal of Marine Science* 63(2):320–325.
Österblom, H., Hansson, S., Larsson, U., Hjerne, O., Wulff, F., Elmgren, R., & Folke, C. 2007. Human-induced trophic cascades and ecological regime shifts in the Baltic Sea. *Ecosystems* 10(6):877–889.
Pauly, D., Christensen, V., Guénette, S., Pitcher, T., Sumaila, U., Walters, C., Watson, R., & Zeller, D. 2002. Towards sustainability in world fisheries. *Nature* 418(6898):689–695.
Pauly, D. 2006. Unsustainable marine fisheries. *Sustainable Development Law & Policy* 7(1):10–12.
Poulter, S. 2007. The "sham" of organic cod farming, by expert. *Daily Mail* February 15:12.
Powell, K. 2003. Eat your veg. *Nature* 426(6965):378–379.
Rawlinson, P. & Forster, A. 2000. *The Economics of Recirculation Aquaculture*. International Institute of Fisheries Economics and Trade Conference. July 10–14, Oregon State University, IIDET. http://oregonstate.edu/dept/IIFET/2000/papers/rawlinson.pdf.
Reuters. 2008. Iceland Bank Kaupthing Files for US Bankruptcy. http://www.reuters.com/article/usDollarRpt/idUSN015013462008 1201. March 1, 2009.
Ritchie, J. & Spencer, L. 1994. Qualitative data analysis for applied policy research. In A. Bryman & R. Burgess (Eds.), *Analyzing Qualitative Data*. pp. 173–194. New York: Routledge.
Rosenlund, G. & Skretting, M. 2006. Worldwide status and perspective on gadoid culture. *ICES Journal of Marine Science* 63(2):194–197.
Samuelsen, O., Nerland, A., Jørgensen, T., Schrøder, M., Svåsand, T., & Bergh, Ø. 2006. Viral and bacterial diseases of Atlantic cod *Gadus morhua*, their prophylaxis and treatment: a review. *Diseases of Aquatic Organisms* 71(3):239–254.
Scottish Executive. 2006. *Scottish Fish Farms Annual Production Survey, 2005*. Aberdeen: Fisheries Research Service. http://www.marlab.ac.uk/FRS.Web/Uploads/Documents/survey2005.pdf.
Soto, D., Jara, F., & Moreno, C. 2001. Escaped salmon in the inner seas, southern Chile: facing ecological and social conflicts. *Ecological Applications* 11(6):1750–1762.
Standal, D. & Bouwer Utne, I. 2007. Can cod farming affect cod fishing? A system evaluation of sustainability. *Marine Policy* 31(4):527–534.
Tilseth, S. 1990. New marine fish species for cold-water farming. *Aquaculture* 85(1–4):235–245.
Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A., Kautsky, N., & Yarish, C. 2003. Integrated mariculture: asking the right questions. *Aquaculture* 226(1–4):69–90.
Walden, J. 2000. The Atlantic cod: the potential for farming in Shetland. *Fisheries Information Note* 3:January.
Wurts, W. 2000. Sustainable aquaculture in the twenty-first century. *Reviews in Fisheries Science* 8(2):141–150.

ARTICLE

# Ecosystem services and agricultural land-use practices: a case study of the Chittagong Hill Tracts of Bangladesh

**Golam Rasul**
Economic Analysis Division, Sustainable Livelihood & Poverty Reduction, International Centre for Integrated Mountain Development (ICIMOD), PO Box 3226, Kathmandu, Nepal (email:grasul@icimod.org)

Land degradation due to inappropriate agricultural activities, as well as the environmental and social effects associated with these practices, is accelerating in many developing regions of the world. This trend underlines the importance of measuring environmental costs and benefits to improve policy making with respect to land use and agriculture. Using nonmarket valuation techniques, this article estimates the value of environmental services associated with four agricultural land-use systems in the Chittagong Hill Tracts of Bangladesh and compares their relative profitability from private and social perspectives. The financial analysis reveals that annual cash crops are the most profitable short-term land use and agroforestry is the least profitable, with horticulture and farm forestry providing benefits intermediate between these two systems. However, the relatively larger returns from annual cash cropping lead to higher environmental costs such as soil erosion, forfeited carbon sequestration, and biodiversity loss. When the environmental costs are taken into account, annual cash crops appear to be the most costly land-use system, with agroforestry and farm forestry becoming more profitable. The findings demonstrate the tradeoffs and synergies between relatively more environmentally sustainable and harmful land-use practices. Financial incentives to encourage more prudent agricultural activities are needed to transform tradeoffs into synergies. This article examines different financial incentive mechanisms—including payments for environmental services—and makes several policy recommendations.

KEYWORDS: agricultural practices, land use, cost-benefit analysis, contingent valuation, socioeconomics, environmental effects

## Introduction

Degradation of natural resources, particularly land and forests, has become a serious concern in developing countries where most rural people depend on these resources for sustenance (FAO, 1999). Deforestation and inappropriate agricultural practices have undermined the productive capacity of approximately two billion hectares (ha) of the world's agricultural land (Pinstrup-Andersen & Pandya-Lorch, 1998). The pace of impairment is highest in mountain areas because of steep slopes and fragile environments (Rasul, 2006).

Like other mountainous areas in South and Southeast Asia, the Chittagong Hill Tracts (CHT), a hilly region in Bangladesh, face serious problems of agricultural land degradation (Shoaib et al. 1998; Gafur, 2001; Rasul, 2006). Four-fifths of the CHT region is steeply sloped. Combined with heavy seasonal rainfall (2,032 to 3,810 millimeters per year) and poor soil structure, the topography poses a serious impediment to annual cultivation in most of the region (96%) that is otherwise suitable for tree farming, agroforestry, horticulture and the cultivation of other perennial crops (FFEI, 1966; SRDI, 1986).

Although several biophysical and geomorphological factors are responsible for land degradation, inappropriate land-use practices have accelerated the rate of harm (Rambo, 1998; Pagiola, 2001). According to the World Resources Institute (1992), over two-thirds of land impairment in Asia is caused by deforestation and poorly suited agricultural practices. Land-use change, including conversion of forestland into agricultural land, not only accelerates land degradation, but also intensifies carbon-dioxide ($CO_2$) emissions and loss of biological resources (Kremen et al. 2000; Jackson et al. 2007). Kremen et al. (2000) estimate that about 20–30% of $CO_2$ emissions worldwide are due to tropical deforestation and land-use changes. Change in land use, particularly conversion to monocropping, has accelerated the loss of agrobiodiversity (Partap & Sthapit, 1998; Jackson et al. 2007).

In CHT, spurred by higher profit opportunities, the cultivation of annual cash crops, particularly ginger, turmeric, and other root products, is steadily increasing on hill slopes. For example, ginger grown under such topographical conditions with intensive tillage practices has increased more than four times, from 1,305 ha in 2003 to 5,764 ha in 2008 (Ahmed,

© 2009 Rasul

2008). Soil loss under annual crops on hill slopes exceeds 100 tons/hectare/year (t/ha/year) (Shoaib et al. 1998; Gafur, 2001; Rasul, 2006). Land degradation and the loss of biological resources raises concerns about the long-term viability of agricultural systems as sustainable development requires that human exploitation of natural resources not exceed the renewal capacity of the Earth's biosphere (WCED, 1987). The principles of sustainability demand that the stock of natural resources and environmental services be maintained to ensure that future generations will be able to meet their needs as we have met ours (Turner et al. 1993; Alauddin, 2004).

While some agricultural practices degrade natural capital, others provide economic benefits and conserve it (Pimentel et al. 1997; Bjoeurklund et al. 1999; Zhang et al. 2007). If public institutions cannot provide incentives for agricultural practices that conserve natural capital, the productive base of a country will shrink (Dasgupta, 2007).

The most important challenge facing developing countries today is how to promote agricultural practices that provide necessary goods and services while conserving natural capital. To design appropriate policies and strategies that encourage sustainable land uses, it is important to recognize the economic value of environmental services and disservices generated by alternative agricultural practices. Policy makers often do not perceive and value these services due to a lack of information in the form of market prices that reflect the monetary value they provide (Barbier, 1999; Bräuer, 2003; Swinton et al. 2007; Nijkamp et al. 2008). Failure to recognize the use and nonuse value of environmental services provided by different land-use systems, such as soil conservation, carbon sequestration, and biodiversity protection, often encourages the implementation of policies that lack incentives for sustainable agricultural practices. As a result, the supply of environmental services remains inadequate. It is, therefore, crucial to estimate the monetary value of alternative agricultural practices to facilitate the integration of environmental costs and benefits into policy making (Bjoueurklund et al. 1999; Bräuer, 2003; Ninan & Sathyapalan, 2005; Swinton et al. 2007).

While quantifying the economic value of environmental services and disservices is useful for informed decision making (Dale & Polasky 2007; Swinton et al. 2007), methodological difficulties remain an obstacle to the making of true comparisons (Bräuer, 2003; Nijkamp et al. 2008). Although several recent attempts have been made to evaluate alternative land-use practices, the focus has remained narrowly centered on specific aspects (Engel et al. 2007). While some studies focus on the economic valuation of soil conservation of alternative agricultural practices (e.g., Rasul & Thapa, 2006; Marta-Pedroso et al. 2007), others consider carbon emission/sequestration (Kremen et al. 2000; Huang & Kronrad, 2001; Olschewski & Benítez, 2005; Zbinden & Lee, 2005; Azqueta & Sotelsek 2007; Tschakert, 2007). Additionally, a few scholars over the last several years have carried out economic valuations of biodiversity conservation (Ninan & Sathyapalan, 2005, Jackson et al. 2007). However, agriculture is a multifunctional activity. Along with producing food, fiber, and other economic goods, an effectively operated farm also protects the environment, generates employment, and sustains rural landscapes (Dale & Polasky 2007; Madureira et al. 2007; Swinton et al. 2007; Zhang et al. 2007). To allow a true comparison of this range of activities, it is necessary to capture key environmental services such as soil conservation, carbon sequestration, and biodiversity protection, along with marketable goods and services (Zbinden & Lee, 2005; Swinton et al. 2007).

In view of this situation, the current study estimates the costs and benefits of four major land-use systems in the CHT region of Bangladesh using nonmarket valuation techniques to account for the soil conservation, carbon sequestration, and biodiversity services and disservices from both private and social perspectives.[1] However, this investigation does not provide a fully detailed valuation of ecosystem services. Instead, the focus is on an assessment of selected ecosystem services based on existing information to facilitate comparative analysis of four alternative land-use systems. The findings of the study have potential value in the design of policies and strategies for promoting sustainable land-use systems and sustaining ecosystem services in the CHT region and elsewhere.

## Valuation of Environmental Services: Methodological Approaches

The introduction of nonmarket valuation of environmental services can be traced back five decades to Hotelling's estimate of travel demand (1949) and to Ciracy-Wantrup's willingness-to-pay (WTP) method (1962). Until recently, application of this approach has been limited by philosophical and methodological obstacles involved in assigning monetary value to nonmarket goods and services. The first challenge that the economist faces in implementing such a procedure is to determine which goods and services to

[1] The private perspective is measured by financial returns while the social perspective is assessed from the standpoint of long-term agronomic sustainability and environmental services and disservices such as soil conservation, carbon sequestration, and biodiversity protection.

assign an economic value. Due to standard assumptions regarding welfare maximization, economists do not normally assign value to goods and services that do not have direct or indirect value to human beings. Accordingly, the goods and services that are not valued by human beings, or are not directly instrumental for enhancing welfare, are not assigned economic value (see Goulder & Kennedy, 1997). This anthropocentric view has been contested by "environmentalists" who believe that all living and nonliving things have "intrinsic" value (i.e., value for their own sake, independent of human utility) (e.g., Barr, 1972; Gill, 1987).

Although this fundamental debate is still ongoing, economists and environmentalists have developed at least a tacit understanding about the major categories of values to be considered in economic valuation (e.g., Pearce & Moran, 1994; Bräuer, 2003). This approach entails the use of a "total economic value" (TEV) framework that incorporates both the "use value" and the "nonuse value" of ecosystem services.[2]

Estimating monetary value for direct-use values is relatively straightforward and involves reliance on existing market prices. More challenging, however, is assigning monetary value to indirect use values and nonuse values that have no market. Over the last several decades, economists have developed methodologies to reveal and measure the intangible benefits of ecosystem services that do not have explicit market values. Several valuation methods have been devised and these techniques can be divided into two broad categories: revealed preference or indirect methods and stated preference or direct methods (Boxall et al. 1996; de Groot et al. 2002; Bräuer, 2003). The revealed preference methods rely on surrogate markets for environmental services to estimate monetary value based on indirect use values (Pearce & Moran, 1994). Inferred values are calculated from data on behavioral changes in genuine markets using the actual purchase and consumption of marketed goods and services that are variously related to the items for which there is no market (Paccagnan, 2007). The following techniques provide the most common strategies for assessing revealed preferences: replacement costs (the cost of replacing a service with a human-made system); changes in productivity; costs of illness; avoided costs (costs that would be incurred if the service were absent); hedonic prices (and estimates of the value of nonmarket goods and services determined by observing behavior in the market for related goods and services); and travel-cost method (de Groot et al. 2002; Paccagnan, 2007).

The "stated preference" method estimates the monetary value of environmental services by asking people how much money they are willing to pay for a particular environmental service or how much they are willing to accept as compensation if the service were to be eliminated (Boxall et al. 1996; Birol et al. 2006). The two primary types of stated preference methods are the contingent valuation method (CVM) and conjoint analysis. CVM, which is useful for estimating the values for goods and services that have neither explicit nor implicit prices, is the most commonly used of the two options. Conjoint analysis is conceptually similar to CVM, but it asks respondents to rank alternatives rather than make direct statements relating to value (Arifin et al. 2009).

An alternative way to elicit stated preferences asks people how many times they are willing to visit a given recreational site instead of how much they are willing to pay to have such a facility (Birol et al. 2006). This technique is usually referred to as "contingent behavior" as it focuses on hypothetical activities. Another stated preference method now gaining attention is "group valuation," or "discourse-based valuation," in which a group of stakeholders is brought together to discuss ecosystem-service values (de Groot et al. 2002; Wilson & Howarth, 2002).

Various techniques are used to elicit the value of nonmarket goods and services. The most common are the bidding game, payment card, and open-ended and dichotomous choice (Boyle et al. 1998; Boyle, 2003). These methodologies, however, are still in their development stages and are being refined to improve estimations of the values of nonmarketed ecosystem services.

In stated preference methods, special care needs to be given to the design of questions and the selection of the appropriate approach. There can sometimes be a bias in WTP toward consumer rather than producer preferences since the value of environmental services may differ between them. When the supply of environmental services is less than socially desired, it is advisable to estimate the value from the

[2] Use values are further divided into direct use values, indirect use values, and option values. Direct use values derive from both consumptive uses of ecosystem goods and services such as food, fibers, fuel woods, medicine, and nonconsumptive uses such as satisfaction and recreation. Indirect use values arise from indirect ecosystem support in production, regulation, and supporting services such as nutrient cycling, climate regulation, hydrological recycling, and flood control (MEA, 2005). Option values are associated with the social value of maintaining the availability of certain ecosystem services as it is difficult to definitely anticipate future demand for such resources and their availability. Nonuse values are commonly divided into existence values and bequest values. Existence values derive from the economic value people place on knowledge that certain ecosystems resources exist, even if they have no intention of actually using them. Bequest values are related to the satisfaction that people derive from ensuring the continued existence of ecosystem resources for future generations (Swinton et al. 2007).

producers' willingness to supply those services (known as "willingness to accept") rather than from the standpoint of consumers' WTP (Swinton et al. 2007).

Both stated and revealed preference methods have advantages and disadvantages. The revealed preference method has a higher general acceptance, as values are estimates based on certain physical parameters or data and these approximations engender greater confidence than data generated by interviews about a hypothetical situation (Paccagnan, 2007). With hypothetical questions, stated preference may differ from a real situation (Diamond & Hasuman, 1994; Paccagnan, 2007). It is, however, not always possible to get a physical reference point, or proxy indicator, when estimating nonuse values. This problem emerges, for example, when estimating decreased agricultural productivity due to increased soil erosion or declining property value due to deteriorating environmental quality. When no surrogate can be found, the stated preference method is the only option (Boxall et al. 1996). The choice of valuation methods, therefore, depends upon the nature of the goods and services, and/or the type of benefits being measured. Recent approaches to improve estimation combine revealed and stated preference methods (Paccagnan, 2007) and a few empirical studies use both methods (e.g. Whitehead et al. 2000; Andersson, 2007).

## Research Methods

### *Study Area*

The study is conducted in the CHT region located in the southeastern part of Bangladesh and covering three hill districts—Rangamanti, Bandarban, and Khagrachari (Figure 1). With an area of 5,089 square miles, CHT covers about one-tenth of the Bangladeshi territory and is surrounded by India in the north and east, Myanmar in the southeast, the Chittagong district in the west, and Cox's Bazar in the southwest. This area is geographically and culturally distinct from the rest of the country and is inhabited by a variety of tribal ethnic groups. According to the 2001 census, 1,400,000 people live in the region. Twelve ethnic groups (*Chakma*, *Marma*, *Tripura*, *Mro*, *Bawm*, *Tanchangya*, *Kheyang*, *Pankhu*, *Chak*, *Lushai*, *Khumi*, and *Rakhain*) comprise the majority. The remaining residents are Bengalis who have migrated from the adjacent plain region over the last several decades. Agriculture is the main source of livelihood of both tribal and nontribal residents. Nonfarm income opportunities are very limited, and in some areas nonexistent. The agricultural land in CHT can be broadly divided into three classes. Class I lands (normally located in the valleys) account for a small percentage of the total area and are considered appropriate for all types of agriculture. Class II lands have gentle slopes and are suitable for terrace cultivation. Class III lands are steeply sloping and are regarded as only usable for nonarable activities such as forestry and horticulture (Rasul, 2006).

Detailed fieldwork was conducted in the Bandarban district from January to July 2002. The *Marma* and *Mro* are the largest tribal communities in Bandarban, followed by the *Bawm*. These three groups account for about 80% of the district's total tribal population. The *Marma* normally live near streams and rivers and the *Mro* and *Bawm* peoples usually live in higher elevations on hill slopes. *Marmas* are Buddhist and *Bawms* are Christian. In terms of comparative socioeconomic status, the *Marmas* and *Bawms* are relatively more affluent than the *Mros*.

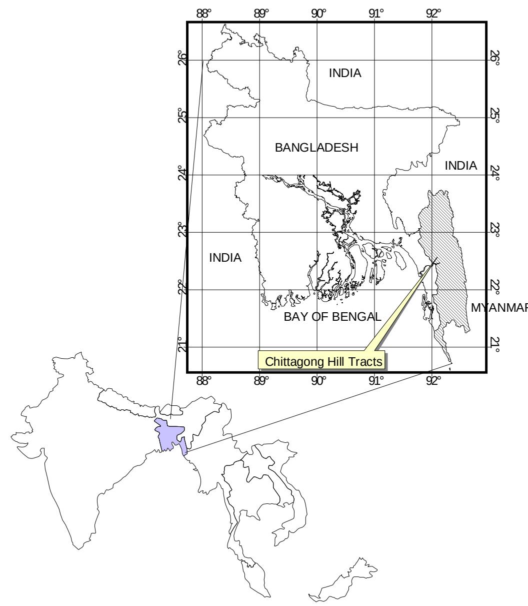


**Figure 1** The study area: the Chittagong Hill Tracts of Bangladesh.

### *Data Collection Methods*

This study is based on both primary and secondary data. Primary data were assembled through a household survey, focus groups, key informant interviews, and case studies. The research was carried out in two stages in two representative subdistricts, namely *Bandarban Sadar* and *Alikadam* in the Bandarban district of CHT. Initial information on farmers' socioeconomic conditions, land-use practices, land-management activities, farming systems, employment, income, and personal experiences in the four different land-use types was collected from 304 randomly sampled farm households using a standard questionnaire. This phase was followed by the collection of additional information on more specific land-use practices such as area under cultivation, volumes and prices of inputs and outputs, and land-management activities and time spent on each activity. Data were collected through detailed interviews administered to a random sample of farm households that had participated in the first stage of research. The information provided by individual farmers was verified through focus groups and interviews with key informants, agricultural extension agents, forestry officials, local nongovernmental organization (NGO) workers, and, particularly, land-user groups through focus-group discussions.

### *Specification of Land-Use Systems Under Study*

Several land-use practices are currently evinced in the study area. Although once *Jhum* (shifting cultivation) was the dominant type of agriculture in the CHT region, it is increasingly being replaced by more financially attractive alternatives. Due to their growing importance, this study considers four land-use systems: annual cash crops (such as turmeric and ginger), horticulture, agroforestry, and farm forestry.

Although these land-use systems are distinct economic activities, farmers variously engage in several of them on a concurrent basis. For example, a farmer who primarily cultivates cash crops for market may also plant trees near the house or on a dyke or devote some farmland to fruit trees for household consumption. Farmers rarely keep records of inputs, outputs, and prices associated with these types of minor activities and this situation presents a challenge for the comprehensive collection of quality data on each land-use system. Through examination of local conditions, it was deemed expedient to use certain criteria in determining samples to ensure that they reflected the genuine characteristics of the entire land-use group.

### *Sampling Procedures*

Agroforestry is characterized by a blend of trees and several field crops. The analysis therefore accounts for the costs and benefits of all major crops and tree species within the agroforestry system. Farmers who planted trees deliberately in association with field crops and earned some amount of income from them during the year 2001 were considered eligible for the interview. From a total of 103 farmers who had initially been interviewed and had planted trees, 27 farmers met these criteria. One-third of these farmers, chosen at random, were interviewed.[3]

For the other three types of land uses, the most dominant crop or tree species was selected. Ginger was thus chosen from among the annual cash crops, pineapple for the horticulture system, and *gamar* (*Gmelina arborea Roxb.*) for timber plantations. The methodology used to determine representative crops or tree species, as well as the procedures employed to identify eligible households for each land-use system, is described below.

Ginger, aroid, and turmeric are the major cash crops grown in the study area, with ginger the most important both in terms of its contribution to household income and the proportion of land under cultivation. Farmers cultivating ginger for the last twelve years and earning at least 10% of their household income from annual cash crops were considered for evaluation. Of the 86 farm households cultivating annual cash crops, 32 met the relevant criteria. Eleven of them were randomly selected for more detailed consideration.

Pineapple, banana, and papaya are the main crops farmed under the horticulture system. Pineapple was chosen for evaluation as it is dominant in terms of proportion of land under cultivation and contribution to household income. Farmers whose proceeds from horticulture accounted for at least one-fourth of total household income and who had been cultivating pineapple for at least twelve years were considered for interviews. Of the 112 farmers practicing horticulture, 52 met these criteria and eighteen were randomly selected for interviews.

The major timber species grown in the study area are *gamar* (*Gmelina arborea Roxb.*), teak (*Tectona grandis*), *akashmoni* (*Acacia auriculiformis*), *mangium* (*Acacia mangium*), *koroi* (*Albizia sp.*), *kanak* (*Schima wallichii*), *goda* (*Vitex sp.*), *chapalish* (*Artocarpus chama*), mahogany (*Swietenia macrophylla*), and *simul* (*Bombax ceiba*). The most commonly grown of these are *gamar* and teak. Most small farmers grow *gamar* because it matures relatively quickly—after only ten to twelve years—and is well adapted to local conditions with the wood used mainly for construction. Teak is a hardwood species that matures in 30–40 years and is used mainly for furniture and construction. We therefore considered *gamar* as representative of the tree-farming land-use system. Farmers who had planted at least 200 *gamar* trees and harvested timber during 2001 were included in the research design. Of 74 farmers growing trees for commercial purposes, 25 met these criteria. One-third of them were chosen at random for interviews.[4]

---

[3] It is generally expected that a sampling protocol involving one-third of the overall population will represent the sample characteristics properly. When the population is large, a sample size that is less than one-third can suffice.

[4] One may question why different criteria have been used for selecting samples from different land-use groups. Given the diversity of land uses practiced by farmers in the study area, adopting

### *Estimation of Financial Costs and Benefits*

The various land-use systems each have different production cycles. For annual crops, the production cycle is one year, horticulture is five to six years, and farm forestry is twelve years. To compare the costs and benefits of land-use systems, a twelve-year time horizon was considered in an analysis based on inputs, outputs, and farm-gate prices of produce.[5] To facilitate the comparison, all costs and benefits were brought to present value by using a discounting method. The opportunity cost of labor in the study area varies by gender and season. Following the prevailing wage-labor rates, US$1.57 (Taka 90) and US$1.05 (Taka 60) were considered to be the daily per capita opportunity costs of adult male and female workers, respectively.[6] The national interest rate for agricultural credit is 11% and farmers incur additional administrative costs of about 1% to secure credit. Following Kumar (2002), a discount rate of 12% was considered to reflect the cost of capital.

### *Estimation of Returns to Land*

The return to land was a criterion to evaluate each land-use system. Given the scarcity of land in the CHT region, both private and social objectives aim to maximize returns from a unit of land. Returns to land are expressed by net present value (NPV) which discounts the streams of benefits and costs back to a base year. The NPV of each land-use system over a period of twelve years was calculated using the following equation:

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \qquad (1)$$

Where,

$B_t$ = land-use specific benefits accrued over the twelve years,
$C_t$ = land-use specific costs incurred over the twelve years,
$r$ = the discount rate, 12%, and
$t$ = time period, twelve years

sample criteria was found to be useful. Although this approach reduced sample size, it helped to identify representative samples and more representative data.

5 Because different land uses have different time horizons, without a twelve-year window, assessing certain costs and benefits would have been difficult.

6 Some scholars argue that the wage rate does not always reflect the true opportunity cost of time. In the CHT region, other than wage labor, tribal people engage in extractive activities whereby men collect bamboo and women harvest wild vegetables, fruits, nuts, and firewood to sell to the market. However, income from extractive activities varies considerably by resource availability and seasonality. Given this variability, wage labor has been considered as the opportunity cost of labor. The exchange rate at the time of publication was 69 Bangladeshi taka to one US dollar.

### *Estimation of Environmental Services*

Agricultural land use can generate both positive and negative externalities. The common positive externalities are soil and water conservation, carbon sequestration, biodiversity protection, and scenic beauty. Negative externalities are soil erosion, land degradation, biodiversity loss, carbon emissions, and water-quality deterioration (Zbiden & Lee, 2005). As the externalities vary from one land use to another, it is necessary to value the environmental services in competitive land-use systems. In view of this situation, estimates were made of the value of carbon sequestration and biodiversity protection and the cost of soil erosion associated with each land-use system.

### *Estimation of Soil Erosion*

Soil erosion has both onsite and offsite effects. The onsite effects include soil-nutrient depletion and deterioration in the physical and biological structure of the soil that cannot be easily replenished in the short term (Attaviroj, 1990; Alfsen & Franco, 1996). Since no other data were available to capture the onsite and offsite effects of soil erosion, only the cost of nutrient depletion was considered. Some scholars (e.g., Barbier, 1999; Gafur, 2001; Wiebe, 2002) have argued that though partial, such an analysis provides a better idea about the environmental costs and benefits of alternative land uses than simple subjective assessment. The most significant onsite effect of soil erosion is the loss of soil fertility that results from the depletion of organic matter and decreased availability of phosphorous, nitrogen, potassium, and other trace elements (Attaviroj, 1990; Alfsen & Franco, 1996; Barbier, 1999). Different approaches have been developed to estimate the value of such nonmarket goods and services (Costanza et al. 1997; Daily et al. 2000; Gunatilake & Vieth, 2000; de Groot et al. 2002). Following several other studies in Asia (e.g., Salzer, 1993; Samarakoon & Abeygunawardena, 1995; Marta-Pedroso et al. 2007), the replacement-cost method for valuation of soil erosion was adopted. To estimate the reliable value of soil loss, the natural rate of soil formation is deducted from the rate of erosion. Salzer (1993) reported that the natural rate of soil formation in temperate climates is about ten tons/ha/year. In Thailand, the same author estimated that the rate of soil formation was fifteen tons/ha/year. Since this study area is similar to CHT in terms of climatic condition and topography, a soil formation rate of fifteen tons/ha/year was assumed.[7]

7 While the rate of soil formation varies from one land use to another, I use the uniform rate of soil formation due to lack of land-use specific soil formation data.

### *Estimation of Carbon Sequestration and Biodiversity Services*

In addition to soil conservation, the different land uses have varying impacts on many other environmental and social services (Pagiola et al. 2007; Schrag, 2007). The monetary value of biodiversity services and carbon sequestration associated with each land-use system was estimated following Pagiola et al. (2004) and Pagiola et al. (2007). While estimation of carbon sequestration is relatively straightforward (Huang & Kronrad, 2001; Olschewski & Benítez, 2005; Zbinden & Lee, 2005; Azqueta & Sotelsek, 2007), approximating the economic value of biodiversity is extremely difficult (Pagiola et al. 2004, Jackson et al. 2007; Nijkamp et al. 2008). Realizing the difficulties, Pagiola et al. (2004) developed an index of biodiversity for different land uses that ranges from 0 to 1, with 0 for annual crops (e.g., grains, tubers) and 1 for primary forest. Other land uses reside between these two extremes. Although this index is a proxy measure and may vary considerably depending on biophysical conditions, it is used to estimate the value of biodiversity services and carbon sequestration as no other precise method is available within the confines of this study. Following the work of Pagiola and his colleagues, the values of carbon sequestration and biodiversity services were estimated with the following formulas.

*Index of carbon sequestration services (ICSS)* =
Point of carbon sequestration in specific land use x Price of carbon (ton/year)

*Index of biodiversity services (IBS)* =
Point of biodiversity in specific land use x Price of biodiversity services (ha/year)

Separate indices were developed for the carbon-sequestration and biodiversity-protection benefits of each land-use system and then aggregated. This approach is similar to that of the environmental benefit index used in the United States Conservation Reserve Program.

Although these indices have been used in several studies to value environmental services, the rate of payment has varied. While Pagiola et al. (2004) estimated US$75 point/year payment for environmental services, Costa Rica's *pagos por servicios ambientales* (payments for environmental services) program pays US$45 ha/year for environmental services (Zbinden & Lee, 2005). This study uses US$45 per point of environmental services, with 25% of the value discounted on the basis that some of the products and biomass will be used by the farm households themselves for fuel, fodder, and other subsistence purposes. This adjustment yields US$33.75 point/ha for environmental services, reflecting the sum of the carbon-sequestration and biodiversity-protection services. The sum, in fact, is equivalent to farmers' willingness to accept (WTA) to manage/supply environmental services in exchange for a given amount of remuneration.

## Results and Discussion

### *Financial Performance of Alternative Land-Use Systems: Private Perspective*

The financial analysis (excluding environmental costs) to estimate the discounted costs and benefits of products produced under the four land-use systems demonstrates that the highest gross benefit (measured as US$/ha/year) is from annual cash crops followed by horticulture and tree farming (Table 1). Gross benefit is lowest for the agroforestry land-use system. Although the gross benefit reflects the relative benefit size, it does not indicate the financial performance of the respective land-use systems because costs are not considered. The NPV is the common indicator of financial performance as it takes into account both costs and income of different activities (Tomich et al. 1998). In terms of NPV, annual cash crops appear to be the best performer followed by horticulture and tree farming. Agroforestry has the lowest NPV. The return from annual cash crops is about three times higher than that from agroforestry. Similarly, return to labor is highest in annual cash crops and lowest in agroforestry, with horticulture and tree farming falling between these two alternatives. The cultivation of annual cash crops also provides relatively quick returns and tree farming requires the longest time to begin generating an income stream. As discussed above, this situation has serious implications for the adoption of more sustainable land-use practices. The smallholders, who have limited capital and need to realize immediate returns, may not be able to alter current cultivation patterns without external support. The price of labor inputs is lowest in tree farming and highest in annual cash crops. This result suggests that moving from cash crops to perennial crops may not be viable for households with surplus labor in the absence of alternative employment opportunities.

### *Economic Performance of Alternative Land-Use Systems: Social Perspective*

The preceding financial analysis, however, does not address the long-term environmental and social benefits such as soil conservation, agronomic sustainability, carbon sequestration, and biodiversity protection of contemporary land-use practices. In the CHT region, the soil-loss rate is very high (Table 2) and this situation accelerates nutrient depletion and

**Table 1** Financial performance of alternative land-use systems.

| | Annual Cash Crops[a] | Horticulture[b] | Agroforestry[c] | Farm Forestry[d] |
|---|---|---|---|---|
| Gross benefits (US$/ha) | 4,867.20 | 2,331.77 | 1,768.12 | 2,314.86[e] |
| Total costs (US$/ha) | 3,924.70 | 1,725.40 | 1,379.77 | 1,791.67 |
| Labor costs (US$/ha)[f] | 2,176.19 (55%) | 1,057.37 (61%) | 992.86 (72%) | 962.91 (51%) |
| Non-labor costs (US$/ha)[g] | 1,748.51 (45%) | 668.03 (39%) | 386.88 (28%) | 872.08 (49%) |
| **Financial performance** | | | | |
| Net financial benefits (NPV) (US$/ha)[h] | 942.51 | 606.36 | 388.40 | 523.21 |
| Initial establishment costs (US$/ha) | 0 | 311.56 | 234.91 | 559.00 |

[a] Ginger is considered as a representative annual cash crop.
[b] Pineapple is considered as a representative horticultural crop.
[c] A typical agroforestry farm has annual crops and tree crops. The latter includes both fruit trees and timber trees. Average production of each crop and corresponding farm-gate prices were used to calculate gross benefits.
[e] Average production was 2,100 cubic feet (cft) of timber over twelve years. Average farm-gate price was US$1.58/cft. Seven or eight years after planting, farmers undertake a major thinning from which material is sold as fuel wood to brick factories and tobacco processors. Average return per household from thinning was US$526.
[f] Labor costs include selection, slashing, burning, cleaning, land preparing, planting, weeding, fertilizing, harvesting, and carrying.
[g] Non-labor costs include seeds, seedlings, fertilizers, pesticides, and interest on capital.
[h] With opportunity cost of household labor.

threatens the long-term sustainability of agricultural systems. To assess the actual costs and benefits of alternative land-use systems, the monetary value of positive and negative externalities associated with each cultivation alternative is estimated based on the methodologies explained above. When the economic costs and benefits of externalities associated with each land-use system are taken into account, the economic value of soil-nutrient depletion ranges from US$16 ha/year under horticulture to US$443 ha/year under annual cash crops (Table 3). Efforts to replenish the lost soil fertility would entail substantial increases in production costs. However, individual farmers generally ignore soil-nutrient loss when making land-use decisions due to the lack of explicit market value, although these nutrients are essential to production and ensure long-term sustainability.

**Table 2** Soil erosion in different agricultural land-use systems.

| Land use | | Soil loss (tons/ha/year) | Average soil loss (tons/ha/year) |
|---|---|---|---|
| Annual crops (mainly root crops such as ginger, | Conventional tillage: hoeing without mulch | 88.85[a] 109.45[b] | 99.15 |
| *mukhi kachu (Colocasia esculanta)*, turmeric) | Conventional tillage: hoeing with mulch | 35.43[c] 34.89[b] | 35.16 |
| Pineapple (horticulture) | | 18.05[c] | 18.05 |
| Agroforestry, tree farming, mixed plantation/fallow *jhum* (five-year rotation) | | 10.00[d] | 10.00 |

[a] Shaheed, 1995 and Shoaib et al. 1998; [b] Uddin et al. 1992;
[c] Chowdhury, 2001; [d] Gafur, 2001

The cost of soil erosion under the annual cash-crop system accounts for about 11% of the total production costs. However, under the agroforestry and tree-farming systems, farmers have savings of about US$26 ha/year, as the soil-formation rate exceeds the erosion rate. This benefit substantially changes the profitability of these land-use systems (Table 3 and Table 4) and horticulture emerges as the most profitable land use with tree farming in the second position. By contrast, the profitability of annual cash cropping is considerably reduced because of a high rate of nutrient depletion through soil erosion. This estimate is, however, conservative. The actual cost of nutrient loss may be higher as the price that farmers are paying for inorganic fertilizers is normally higher than the border price used in the analysis.

### *Carbon Sequestration and Biodiversity Protection*

The value of biodiversity services varies considerably across the land-use systems. In terms of species conservation, annual cash crops do not provide any positive environmental services and agroforestry provides the highest benefits. Farm forestry generates the largest environmental services and the highest benefits in terms of carbon sequestration. Agroforestry and horticulture fall between these two alternatives (Table 5). There are, however, considerable variations among agroforestry, farm forestry, and horticulture with respect to carbon sequestration and biodiversity protection. When the benefits of environmental services are taken into account, annual cash crops become the least profitable land-use practice and farm forestry the most profitable option, with

**Table 3** Economic valuation of soil loss by land-use systems.

| | | Annual Cash Crops | Horticulture | Agroforestry | Farm Forestry |
|---|---|---|---|---|---|
| Soil-loss rate (tons/ha/year)[a] | | 99.15 | 18.05 | 10.00 | 10.00 |
| Natural rate of soil formation (tons/ha/year) | | 15.00 | 15.00 | 15.00 | 15.00 |
| Net soil loss/gain (tons/ha/year) | | - 84.15 | - 3.05 | 5.00 | 5.00 |
| Loss equivalent to inorganic fertilizers (kg/ton/eroded material)[b] | N (total) – Urea | 755.98 | 27.40 | 44.91 | 44.91 |
| | P (available) – TSP | 38.47 | 1.39 | 2.29 | 2.29 |
| | K (exchangeable) – MP | 58.90 | 2.14 | 3.50 | 3.50 |
| | Ca lime | 332.39 | 12.05 | 19.75 | 19.75 |
| | Organic Matter (kg) | 5,370.45 | 194.65 | 319.10 | 319.10 |
| | Total | 6,556.19 | 237.63 | 389.55 | 389.55 |
| Economic loss/gain (US$/ha)[c] | N (total) | 127.32 | 4.61 | 7.56 | 7.56 |
| | P (available) | 7.70 | 0.28 | 0.46 | 0.46 |
| | K (exchangeable) | 8.53 | 0.32 | 0.51 | 0.51 |
| | Ca lime | 17.49 | 0.63 | 1.04 | 1.04 |
| | Organic Matter | 282.63 | 10.25 | 16.79 | 16.79 |
| | Total | - 443.67 | -16.09 | 26.35 | 26.35 |

[a] For source of average soil-loss rate under different land-use systems, see last column of Table 1.

[b] Loss equivalent to inorganic fertilizers = the net soil-loss rate x nutrient lost per ton eroded soil x nutrient: fertilizer-conversion factor. According to Gafur (2001), nutrient loss (kg/ton of eroded soil) is: N (total) = 4.14; P (available) = 0.09; K (exchangeable) = 0.35; Ca = 1.58, and OM = 63.82. Nutrient: fertilizer-conversion factors are adopted from Bangladesh Agricultural Research Council (1997) and are as follows: N – urea 2.17; P (available) – TSP 5.08; K (exchangeable) – MP 2.00; Ca – lime 2.50.

[c] Economic loss was calculated based on the border price of inorganic fertilizers. Border prices were determined by taking average of c.i.f. prices. The prices used were as follows: Urea = 0.168 US$/kg, P = 0.20 US$/kg, K = 0.145 US$/kg, lime = 0.05 US$/kg, and OM = 0.05 US$/kg.

the returns from agroforestry almost twice those from annual crops.

The analysis reveals a tradeoff between short-term profitability and environmental sustainability. For the individual farmer who wants to maximize his returns, the cultivation of annual cash crops is the preferable option. However, from an environmental and long-term economic perspective, annual cash crops provide the least desirable land use as they decrease natural capital through high rates of soil erosion and biodiversity loss. The tradeoff is highest in agroforestry and lowest in horticulture. If farmers move from annual cash crops to agroforestry, the opportunity cost is US$554 ha/year (not accounting for soil and nutrient depletion). To minimize this tradeoff, such a move needs to be examined from both a sustainability and a stakeholder perspective. Table 6 presents the relationship among profitability, sustainability, and various stakeholders' interests and reveals a conflict among the three major stakeholders, namely local land users, national government, and the global community. Financial return is the prime concern of private land users. Agronomic sustainability also affects them, of course, as soil erosion depletes on-farm nutrient status and reduces longer-term productivity. However, due to a short time horizon and a high discount rate, farmers generally do not consider the value of soil conservation. Moreover, many farmers in CHT use common property land for growing annual crops, shifting their plots every two to three years, and thus do not incur the costs of nutrient depletion and soil erosion. Nevertheless, this land-use practice depletes natural capital at the national scale, a trend that government has a strong interest in avoiding. Likewise, local land users have little interest in carbon sequestration and biodiversity protection, as they receive little benefit in the short term from these activities, although the global community as a whole does benefit. The land-use systems that provide higher benefits at an international scale do not generate higher annual economic returns for the farmer. Therefore, there is no straightforward

**Table 4** Economic performance of alternative land use systems.

| | Annual Cash Crops | Horticulture | Agroforestry | Farm Forestry |
|---|---|---|---|---|
| Gross benefits (US$/ha) | 4,867.20 | 2,331.77 | 1,768.12 | 2,314.86 |
| Net financial benefits (NPV) (US$/ha) | 942.50 | 606.36 | 388.40 | 523.21 |
| Net soil loss/gain (ton/ha) | - 84.15 | - 3.05 | 5.00 | 5.00 |
| Economic loss/gain due to soil loss (US$/ha) | -443.67 | -16.09 | 26.35 | 26.35 |
| Net economic benefits (NPV) (US$/ha) | 498.84 | 590.28 | 414.75 | 549.56 |
| Return to labor (US$/person-day) | 1.95 | 1.77 | 2.07 | 1.93 |

**Table 5** Performance of alternative land-use systems with biodiversity and carbon sequestration value.

| | Annual Cash Crops | Horticulture | Agroforestry | Farm Forestry |
|---|---|---|---|---|
| Net financial benefits (NPV) (US$/ha)[a] | 942.50 | 606.36 | 388.40 | 523.21 |
| Net soil loss/gain (tons/ha)[a] | -84.15 | -3.05 | 5.00 | 5.00 |
| Economic loss/gain due to soil loss (US$/ha)[a] | -443.67 | -6.09 | 26.35 | 26.35 |
| Biodiversity index[b] | 0.00 | 0.30 | 0.60 | 0.40 |
| Biodiversity services (US$/ha) | 0.00 | 121.5 | 243.00 | 162.00 |
| Carbon sequestration[b] | 0.00 | 0.40 | 0.50 | 0.80 |
| Carbon sequestration services (US$/ha) | 0.00 | 162.00 | 202.50 | 324.00 |
| Total economic benefits (NPV) (US$/ha) | 498.33 | 873.77 | 860.25 | 1,035.56 |

[a] Figures are derived from the third row of Table 4
[b] Indices of biodiversity and carbon sequestration are from Pagiola et al. (2004). For details, see Pagiola et al. 2004 and Pagiola et al. 2007.

win-win situation. The results suggest a need for a strong role for national government, and perhaps the global community, to reduce the divergence between private and social profitability by providing financial incentives for environmental services, as there is no market value for them.

## Conclusions and Recommendations

This study estimates the costs and benefits of four major land-use systems in the CHT region of Bangladesh. It examines the environmental costs and benefits of soil conservation, carbon sequestration, and biodiversity protection of agricultural practices to facilitate improved policy decisions through a comparison of alternative land-use practices. An integrated approach of combining revealed and stated preferences for the determination of nonmarket values was used to estimate the monetary value of environmental services and disservices generated by the various agricultural practices.

The analyses show that when environmental impacts are disregarded, annual cash crops are financially more attractive than agroforestry, farm forestry, and horticulture. The financial benefits from the cultivation of cash crops exceed the benefits of agroforestry and farm forestry even after the monetary values of soil erosion are accounted for. Along with measuring costs and benefits of agricultural practices, this article also estimates the financial tradeoffs for farmers of moving from one land use to another and provides useful information on the amount of reward/compensation that might be required to minimize the tradeoff. The results demonstrate a significant opportunity cost, from a private perspective, associated with producing and sustaining environmental services within agricultural production systems.

The higher financial benefits associated with annual cash crops, however, are offset by high environmental costs, specifically in terms of soil erosion, carbon emissions, and biodiversity loss, which are major social concerns. The high rate of soil erosion associated with annual cash crops accelerates nutrient depletion and undermines the long-term sustainability of agricultural systems. The foregoing analysis demonstrates that private and social interests diverge, a

**Table 6** Profitability, sustainability, and stakeholders’ interest.

| | | Land Use Types | | | | Stakeholders Interest |
|---|---|---|---|---|---|---|
| | | Annual Cash Crops | Horticulture | Agroforestry | Farm Forestry | |
| Private Perspective | Private profitability[a] | High | Medium | Low | Medium | Land users |
| Social Perspective | Soil conservation[b] | Low | Medium | High | High | Land users and national government |
| | Biodiversity services[c] | Low | Medium | High | Medium | Primarily global community |
| | Carbon sequestration services[d] | Low | Medium | High | High | Primarily global community |
| | Agronomic sustainability[e] | Low | Medium | High | High | Land users and national government |

[a] See Table 3, Row 7.
[b] See Table 5, Row 6.
[c] See Table 5, Row 6.
[d] See Table 5, Row 8.
[e] Agronomic sustainability is understood as soil erosion, soil formation, and biodiversity protection.

pervasive problem in most developing countries (Monke & Pearson, 1989; Pagiola, 2001). This study, however, reveals that the divergence is not genuine in the long term. When the social costs and benefits of soil conservation, carbon sequestration, and biodiversity protection are taken into account, the results show that more sustainable land-use practices are, ultimately, more profitable. From a long-term economic and social perspective, therefore, no tradeoff exists between sustainable and unsustainable land-use practices. This finding is consistent with several theoretical and empirical studies produced to date (Tomich et al. 1998; Rasul & Thapa 2006; Marta-Pedroso et al. 2007; Swinton et al. 2007).

However, the problem remains that no market exists for environmental services. Farmers do not receive any monetary reward for engaging in the production of positive environmental services and so do not take into account these services when making land-use decisions. It is, therefore, important to create a market for environmental services or to develop mechanisms that compensate land users for them. If such mechanisms are not developed farmers in the CHT region (as well as in other mountainous areas of developing countries) are likely to continue to respond to the existing financial incentives and perpetuate unsustainable land-use practices.

The findings of this study are potentially applicable to other mountain areas of South Asia where rural populations depend heavily on land resources for their sustenance and natural resource degradation is extensive. The novelty of this investigation is that it not only estimates use and nonuse values of alternative land-use practices, but also shows the monetary value of different environmental services separately, allowing decision makers to compare alternative land-use practices more precisely. The current analysis, however, uses an environmental service index developed in Latin America to estimate WTA for maintaining environmental services. Eliciting farmers' WTA through a local survey would likely provide a more precise estimate and should be considered in future research.

This evaluation leads to several recommendations to facilitate a shift to more sustainable agricultural practices. An appropriate mechanism should be developed to compensate farmers for the environmental services that their practices generate. Payments for environmental services (PES), if properly implemented, can provide additional income and enhance the profitability of more sustainable land use for small farmers (Pagiola, 2004; Dudley, 2007; Pagiola et al. 2007; Tschakert, 2007). While some environmental services are site specific, others such as carbon sequestration and biodiversity protection are public goods (Dale & Polasky, 2007; Swinton et al. 2007). Moreover, future generations, arguably the beneficiaries of certain measures to promote environmental conservation, are absent from the market. Therefore, the government of Bangladesh should develop appropriate mechanisms to provide remuneration to land users for more sustainable practices following the conservation programs developed elsewhere (Pagiola et al. 2004; Zbinden & Lee, 2005; Pagiola et al. 2007).

In addition, the international community should step forward with the necessary financial and technical support to facilitate a shift from unsustainable to sustainable land-use practices that generate public goods and have global benefits (Kremen et al. 2000; DeFries & Bounoua, 2004). The Kyoto Protocol, specifically the afforestation/reforestation provisions within the clean development mechanisms, has unfortunately to date failed to encourage strategies to capture the environmental benefits generated by smallholders through more sustainable agricultural practices such as farm and community forestry.

Given the complexity of agricultural land use, it may take time to develop appropriate institutional mechanisms for PES. However, governments may immediately provide direct or indirect financial incentives to encourage the adoption of conservation technologies such as nontillage cultivation, mulching, contour planting, alley farming, and terrace construction that can reduce soil erosion and other environmental costs engendered by the cultivation of annual crops. Along with financial incentives, governments may also impose restrictions on growing root crops on steep slopes to generate desired environmental outcomes.

In developing countries such as Bangladesh, financial incentives alone may not be enough to motivate farmers to move from annual crops to perennial crops due to the long phase-in period and the relatively high initial investment costs. Necessary support services, including long-term credit, knowledge transfer, and information on the adoption of perennial crops may need to be provided, as the returns from tree plantations only come after many years.

## Acknowledgement

I am grateful to the three anonymous reviewers for their useful comments and suggestions. Sincere thanks to my colleague Dr. Robert Zomer for his editing assistance. The support provided by my organization, the International Centre for Integrated Mountain Development (ICIMOD), is acknowledged. The perspectives expressed in the paper are mine and are not necessarily related to the views of ICIMOD.

## References


Ahmed, M. 2008. *Feasibility Study on Ginger Production and Processing in Chittagong Hill Tracts of Bangladesh*. Unpublished report for the International Centre for Integrated Mountain Development. Kathmandu: ICIMOD.

Alauddin, M. 2004. Environmentalizing economic development: a south Asian perspective. *Ecological Economics* 51(3):251–270.

Alfsen, K. & Franco, M. 1996. The cost of soil erosion in Nicaragua. *Ecological Economics* 16(2):129–145.

Andersson, J. 2007. The recreational cost of coral bleaching: a stated and revealed preference study of international tourists. *Ecological Economics* 62(3-4):704–715.

Arifin, B., Swallow, B., Suyanto, S., & Coe, R. 2009. A conjoint analysis of farmer preferences for community forestry contracts in the Sumber Jaya Watershed, Indonesia. *Ecological Economics* 68(7):2040–2050.

Attaviroj, P. 1990. Soil erosion and land degradation in the northern Thai uplands. In J. Dixon, D. James, & P. Sherman (Eds.), *Dryland Management: Economics Case Studies.* pp. 18–33. London: Earthscan.

Azqueta, D. & Sotelsek, D. 2007. Valuing nature: from environmental impacts to natural capital. *Ecological Economics* 63(1):22–30.

Bangladesh Agriculture Research Council, 1997. *Fertilizer Recommendation Guide-1997*. BARC Soil Publication 41. Dhaka: BARC.

Barbier, E. 1999. *The Economics of Land Degradation and Rural Poverty Linkages in Africa. UNU/INRA Annual Lectures on Natural Resource Conservation and Management in Africa*. Tokyo: United Nations University Press.

Barr, J. 1972. Man and nature: the ecological controversy and the Old Testament. *Bulletin of the John Rylands Library* 55:9–32.

Birol, E., Kontoleon, A., & Smale, M. 2006. *Combining Revealed and Stated Preference Methods to Assess the Private Value of Agrobiodiversity in Hungarian Home Gardens*. Environment and Production Technology Division Discussion Paper 156. Washington, DC: International Food Policy Research Institute.

Bjoeurklund, J., Karin, E., & Torbjoern, R. 1999. Impact of production intensity on the ability of the agricultural landscape to generate ecosystem services: an example from Sweden. *Ecological Economics* 29(2):269–291.

Boyle, K., Hugh, F., MacDonald, H., & Daniel, W. 1998. Bid design and yea saying in single-bounded, dichotomous-choice questions. *Land Economics* 74(1):49–64.

Boyle, K. 2003. Contingent valuation in practice. In P. Champ, K. Boyle, & T. Brown (Eds.), *A Primer on Nonmarket Valuation.* pp. 111–170. Norwell, MA: Kluwer.

Boxall, P., Adamowicz, W., Swait, J., Williams, M., & Louviere, J. 1996. A comparison of stated preference methods for environmental valuation. *Ecological Economics* 18(3):243–253.

Bräuer, I. 2003. Money as an indicator: to make use of economic evaluation for biodiversity conservation. *Agriculture, Ecosystems and Environment* 98(1–3):483–491.

Chowdhury, M. 2001. *Minimization of Soil Loss, Fertility Development and Upliftment of Farmer's Economy in the Hilly Region*. Bangladesh Agriculture Research Council Report. Joydevpur, Dhaka: Hill Tract Agriculture Research Station, Ramgarh Bangladesh Agriculture Research Institute.

Ciracy-Wantrup, S. 1962. *Resource Conservation: Economics and Policies*. Berkeley: University of California, Division of Agricultural Sciences.

Costanza, R., d'Arge, R., de Groot, Farber, R., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R., Raskin, R., Sutton, R., & van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387(6630):253–260.

Daily, G., Soderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P., Folke, C., Jansson, A., Jansson, B., Kautsky, N., Levin, S., Lubchenco, J., Msaler, K., Simpson, D., Starrett, D., Tilman, D., & Walker, B. 2000. The value of nature and the nature of value. *Science* 289(5478):395–396.

Dale, V. & Polasky, S. 2007. Measures of the effects of agricultural practices on ecosystem services. *Ecological Economics* 64(2):286–296.

Dasgupta, P. 2007. Nature and the economy. *Journal of Applied Ecology* 44(3):475–487.

de Groot, R., Wilson, M., & Boumans, R. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and service. *Ecological Economics* 41(3):393–408.

DeFries, R. & Bounoua, L. 2004. Consequences of land use change for ecosystem services: a future unlike the past. *GeoJournal* 61(4):345–351.

Diamond, P. & Hausman, J. 1994. Contingent valuation: is some number better than no number? *Journal of Economic Perspectives* 8(4):45–64.

Dudley, R. 2007. Payments, penalties, payouts, and environmental ethics: a system dynamics examination. *Sustainability: Science, Practice, & Policy* 3(2):24–35. http://ejournal.nbii.org/archives/vol3iss2/0706-013.dudley.html.

Engel, S., Pagiola, S., & Wunder, S. 2007. Designing payments for environmental services in theory and practice: an overview of the issues. *Ecological Economics* 65(4):663–674.

Forestal Forestry and Engineering International (FFEI). 1966. *Reconnaissance Soil and Land Use Survey: Chittagong Hill Tracts.* Vancouver: FFEI.

Gafur, A. 2001. *Effects of Shifting Cultivation on Soil Properties, Erosion, Nutrient Depletion and Hydrological Responses in Small Watershed of the Chittagong Hill Tracts of Bangladesh*. Unpublished Doctoral Dissertation. Department of Chemistry. The Royal Veterinary and Agricultural University, Copenhagen.

Gill, S. 1987. *Mother Earth: An American Story*. Chicago: University of Chicago Press.

Goulder, L. & Kennedy, D. 1997. Valuing ecosystem services: philosophical bases and empirical methods. In G. Daily (Ed.), *Nature's Services: Societal Dependence on Natural Ecosystems*. pp. 23–48. Washington, DC: Island Press.

Gunatilake, H. & Vieth, G. 2000. Estimation of on-site cost of soil erosion: a comparison of replacement and productivity change. *Journal of Soil and Water Conservation* 55(22):197–204.

Hotelling, H. 1949. Letter to the National Park Service (dated 1947). In United States National Parks Service (Ed.), An *Economic Study of the Monetary Valuation of Recreation in the National Parks*. Washington, DC: Land and Recreational Planning Division, National Park Service.

Huang, C. & Konrad, G. 2001. The cost of sequestering carbon on private forest lands. *Forest Policy and Economics* 2(2):133–142.

Jackson, L., Pascual, U., Brussaard, L., Ruiter, P., & Bawa, K. 2007. Biodiversity in agricultural landscapes: investing without losing interest. *Agriculture, Ecosystems & Environment* 121(3):193–195.

Kremen, C., Niles, J., Dalton, M., Daily, G., Ehrlich, P., Fay, J. Grewal, D., & Guillery, R. 2000. Economic incentives for rain forest conservation across scales. *Science* 288 (5472):1828–1832.

Kumar, S. 2002. Does participation in common pool resource management help the poor? A social cost-benefit analysis of joint forest management in Jharkand, India. *World Development* 30(5):763–782.

Madureira, L., Rambonilaza, T., & Karpinski, I. 2007. Review of methods and evidence for economic valuation of agricultural non-commodity outputs and suggestions to facilitate its application to broader decisional contexts. *Agriculture, Ecosystem & Environment* 120(1):5–21.

Marta-Pedroso, C., Domingos, T., Freitas, H., & de Groot, R. 2007. Cost-benefit analysis of the Zonal Program of Castro Verde (Portugal): highlighting the trade-off between biodiversity and soil conservation. *Soil & Tillage Research* 97(1):79–90.

Millennium Ecosystem Assessment (MEA). 2005. *Living Beyond Our Means: Natural Assets and Human Well-Being*. Statement from the Board. Washington, DC: Millennium Ecosystem Assessment.

Monke, E. & Pearson. S. 1989. *The Policy Analysis Matrix for Agriculture Development.* Ithaca: Cornell University Press.

Nijkamp, P., Vindigni, G., & Nunes, P. 2008. Economic valuation of biodiversity: a comparative study. *Ecological Economics* 67(2):217–231.

Ninan, K. & Sathyapalan, J. 2005. The economics of biodiversity conservation: a study of a coffee growing region in the Western Ghats of India. *Ecological Economics* 55(1):61–72.

Olschewski, R. & Beníez, P. 2005. Secondary forests as temporary carbon sinks: the economic impact of accounting methods on reforestation projects in the tropics. *Ecological Economics* 55(3):380–394.

Paccagnan, V. 2007. *On Combining Stated Preferences and Revealed Preferences Approaches to Evaluate Environmental Resources Having a Recreational Use*. IEFE Working Paper 4. Milan: Centre for Research on Energy and Environmental Economics and Policy, Bocconi University. http://mpra.ub.uni-muenchen.de/5867/1/MPRA_paper_5867.pdf.

Pagiola, S. 2001. Economic analysis of incentives for soil conservation. In D. Sanders, P. Huszar, S. Sombatpanit, & T. Enters (Eds.), *Incentives in Soil Conservation: From Theory to Practice*. pp. 41–56. Enfield, NH: Science Publishers.

Pagiola, S., Agostini, P., Gobbi, J., Hann, C., Ibrahim, M., Murgueitio, E., Ramerez, E., Rosales, M., & Ruíz, J. 2004. *Paying for Biodiversity Conservation Services in Agricultural Landscapes*. Environmental Economics Paper 96. Washington, DC: World Bank. http://129.3.20.41/eps/othr/papers/0405/0405005.pdf.

Pagiola, S., Ramíez, E., Gobbi, J., de Haan, C., Ibrahim, M., Murgueitio, E., & Ruíz, J. 2007. Paying for the environmental services of silvopastoral practices in Nicaragua. *Ecological Economics* 64(2):374–385.

Partap T. & Sthapit B. 1998. *Managing Agrobiodiversity: Farmers' Changing Perspectives and Institutional Responses in the Hindu Kush-Himalayan Region*. Kathmandu: International Centre for Integrated Mountain Development.

Pearce, D. & Moran, D. 1994. *The Economic Value of Biodiversity*. London: Earthscan.

Pimentel, D., Wilson, C., McCullum, R., Huang, P., Dwen, J., Flack, Q., Tran, T., Saltman, T., & Cliff, B. 1997. Economic and environmental benefits of biodiversity. *BioScience* 47(11):747–757.

Pinstrup-Andersen, P. & Pandya-Lorch, R. 1998. Food security and sustainable use of natural resources: a 2020 vision. *Ecological Economics* 26(1):1–10.

Rambo, A. 1998. Introduction. In A. Patanothai (Ed.), *Land Degradation and Agricultural Sustainability*. pp. 1–5. Khon Kaen, Thailand: Khon Kaen University.

Rasul, G. 2006. *Factors Influencing Land-Use Change in Areas with Shifting Cultivation in the Chittagong Hill Tracts of Bangladesh.* Dhaka: AH Development Publishing House.

Rasul, G. & Thapa, G. 2006. Financial and economic suitability of agroforestry as an alternative to shifting cultivation: the case of the Chittagong Hill Tracts, Bangladesh. *Agricultural Systems* 91(1–2):29–50.

Salzer, W. 1993. *Eco-economic Assessment of Agricultural Extension Recommendations for Shifting Cultivators in Northern Thailand.* Unpublished Doctoral Dissertation. Department of Geography. University of Hohenheim, Stuttgart, Germany.

Samarakoon, S. & Abeygunawardena, P. 1995. An economic assessment of on-site effects of soil erosion in potato lands in Nuwara Eliya District of Sri Lanka. *Journal of Sustainable Agriculture* 6(2–3):81–92.

Schrag, D. 2007. Preparing to capture carbon. *Science* 315 (5813):812–813.

Shaheed, S. 1995. *Land Degradation of Hill Areas of Bangladesh.* Unpublished report. Dhaka: Soil Resources Development Institute.

Shoaib, J., Mostafa, G., & Rahman, M. 1998. *Soil Erosion Hazard in Chittagong Hill Tracts: A Case Study.* Annual Report. Dhaka: Soil Resources Development Institute.

Soil Resources Development Institute (SRDI). 1986. *Reconnaissance Soil and Land Use Survey: Chittagong Hill Tracts (1964-1965)*. Dhaka: SRDI.

Suryanata, K. 1994. Fruit trees under contract: tenure and land use change in upland Java, Indonesia. *World Development* 22(10):1567–1578.

Swinton, S., Lupia, F., Robertson, G., & Hamilton, S. 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. *Ecological Economics* 64(2):245–252.

Tomich, T., M. van Noordwijk, S. Budidarsono, A. Gillison, T. Kusumanto, D. Murdiyarso, F. Stolle, & A. Fagi (Eds.). 1998. *Alternatives to Slash-and-Burn in Indonesia, Summary Report of Phase II*. ASB-Indonesia Report Number 8. Bogor: ASB-Indonesia and ICRAF SE Asia.

Tschakert, P. 2007. Environmental services and poverty reduction: options for smallholders in the Sahel. *Agricultural Systems* 94(1):75–86.

Turner, B., R. Moss, & D. Skole (Eds.). 1993. *Relating Land Use and Global Land-Cover Change: A Proposal for an IGBP-HDP Core Project.* Report from the IGBP-HDP Working Group on Land-Use/Land-Cover Change. Stockholm: Royal Swedish Academy of Sciences.

Uddin, M., Islam, M., & Sattar, M. 1992. *Effect of Tillage on Soil Erosion and Yield of Mukhi Kachu in Hilly Region*. Research Report 1991–92. Khagrachari, Bangladesh: Hill Agricultural Research Station.

United Nations Food and Agriculture Organization (UNFAO). 1999. *Poverty Alleviation and Food Security in Asia: Land Resources*. RAP Publication 1999/2. Bangkok: UNFAO, Regional Office for Asia and the Pacific.

Whitehead, J., Haab, T., & Huang, J. 2000**.** Measuring recreation benefits of quality improvements with revealed and stated behavior data. *Resource and Energy Economics* 22(4):339–354.

Wiebe, K. 2002. Does land degradation threaten global agricultural productivity and food security? *Agricultural Outlook* June 2002(AGO-292):27–30.

Wilson, M. & Howarth, R. 2002. Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. *Ecological Economics* 42(3):431–443.

World Commission on Environment and Development (WCED). 1987. *Our Common Future*. New York: Oxford University Press.

World Resources Institute. 1992. *World Resources 1992–93: A Guide to the Global Environment.* Washington, DC: World Resources Institute.

Zbinden, S. & Lee, D. 2005. Paying for environmental services: an analysis of participation in Costa Rica's PSA Program. *World Development* 33(2):255–272.

Zhang, W., Ricketts, T., Kremen, C., Carney, K., & Swinton, S. 2007. Ecosystem services and dis-services to agriculture. *Ecological Economics* 64(2):253–260.

ARTICLE

# Leveraging opportunities for campus sustainability: a case study of water resources

**Kristan Cockerill[1] & Jana Carp[2]**
[1]Appalachian State University, University College, PO Box 32080, Boone, NC 28608 USA (email: cockerillkm@appstate.edu)
[2]Appalachian State University, Department of Geography and Planning, Rankin Science, 572 Rivers Street, Boone, NC 28608 USA

Institutions of higher education are well situated globally for transformation toward sustainability. The case of the Water Resources Planning Committee (WRPC) at Appalachian State University in North Carolina, United States offers insight into how educational institutions might identify and leverage transformative opportunities. The article suggests that a "window of opportunity" can open when diverse actor-groups share a common interest or goal and when individuals are able to "bridge" the groups as a way to create synergy. Once together, these groups can collaborate by sharing knowledge and resources. They do not avoid conflict, but rather constructively use organizational tensions and cultivate flexibility to further common goals. This case study focuses on interrelationships among a public university's teaching and research missions and its place within a broader community as it transforms toward sustainably managing campus-water resources.

KEYWORDS: educational institutions, sustainability, water resources, organizational behavior, watershed management, local planning, cooperation

## Introduction

A growing body of literature on creating a sustainable university focuses on the role of higher education in its broader social context (Sharp, 2002; Cortese, 2003; Calhoun & Cortese, 2005). Integral to these discussions is the need for universities to transform physically, cognitively, and philosophically. Lozano (2006) identifies numerous organizational barriers to implementing sustainable development principles, including internal power struggles and the radical nature of sustainable development relative to traditional management approaches. In an editorial for a special issue of the *International Journal of Sustainability in Higher Education*, Adomssent et al. (2007) state, "sustainable development, and the process of institutional transformation this requires, remains a considerable challenge for universities." Sharp's (2009) recent contribution to this journal on the state of the campus sustainability movement indicates the depth and breadth of this challenge.

While the notion of transformation is inherent in the sustainability literature, what, exactly, institutional transformation implies, and how it might be achieved, has not been adequately specified. Sharp (2009) begins to address this gap by discussing, for example, the role of a "change management function" as part of a long-term institutional strategy. However, little attention has been paid to date to identify the conditions that catalyze the *initiation* of change toward institutional transformation. This article identifies the significant characteristics, embedded in a case study, that demonstrate a "window-of-opportunity" approach for leveraging situations ripe with transformative capacities. The case study focuses on interrelationships among a university's teaching and research missions, its role as an institution, and its place within a broader community. Our approach is consistent with Ehrenfeld's (2008) observation that the key to institutional transformation is focusing on routine processes to identify how and where to make adjustments. He writes that:

> This process of transforming what at first are nonroutine actions into the normal way of behaving is one of the primary objectives of [an] overall design strategy. When the actions become routine, the associated beliefs and norms become embodied. As more and more individuals [or institutions] follow the same new routine, the beliefs and norms will begin to enter the collective, social consciousness.

We argue that institutional transformation requires assimilating concepts and practices based in diverse philosophies and that it resists efforts that would limit either ideas or actions to a single discipline or frame. In preparing this article, the authors have used the theoretical frameworks of complex

© 2009 Cockerill & Carp

systems, participatory planning, production of space, and adaptive management, among others as equally applicable to transformation in general and to our case study in particular. A narrower theoretical focus is also antithetical to one of our main findings: in seeking transformation, there is no linear, one-size-fits-all way forward. Our inductive approach offers a pragmatic understanding of institutional transformation in the context of one university's attempt to become more sustainable. We find that working toward such institutional transformation is not only interdisciplinary; it is also an opportunistic, multiscalar response to external and internal pressures for change. These pressures are expressed in multiple opportunities for action that cannot be prescribed, given the complex social-ecological systems that characterize sustainability and the "irrational life of the institution" that exists parallel with its organizational rationality (Sharp, 2009). Therefore, it is crucial to recognize unprecedented opportunities and to be prepared to leverage such opportunities into action that supports significant transformation.

Using the Water Resources Planning Committee (WRPC) at Appalachian State University (ASU) in North Carolina as a resource-specific case study, we describe how, amid uncertainty, windows of opportunity have opened that have allowed ASU to actively pursue sustainability. The WRPC focuses on water resources, but it potentially serves as a model for similar sustainability-directed efforts because it considers such issues from diverse standpoints. While all universities have interrelated environmental, economic, and social issues, the specifics of what is sustainable will differ in each instance. The transformative process will determine the particular shape of sustainability for any institution.

This article is divided into three sections: Background, Leveraging Windows of Opportunity, and Conclusion. The Background introduces the particular actors and highlights the sequence of events that contributed to the formation of WRPC. The next section theorizes the characteristics of the actors who leveraged the window of opportunity described in the prior section. We describe their interaction using four actor-group capacities that characterize transformative opportunity: synergy, collaboration, conflict, and flexibility. The final section discusses how these relationships are playing out with WRPC as a focal point for considering transformation toward campus sustainability.

## Background to the Case Study

### *Case Study Setting*

Established in 1899, ASU is situated in the Appalachian Mountains and serves about 16,000 students in 140 major programs. The campus is located in downtown Boone, both a prototypical "college town" with a full-time population of about 15,000 people and the urban service center of northwest North Carolina. The area is also a tourist destination, with forests and golf courses, rock cliffs and ski slopes, and the headwaters of four river basins. Despite their importance to unique ecosystems and to downstream human-population centers, these streams have not been well studied or protected from human impact. Agricultural practices have caused significant degradation to water quality and riparian zones. The steady growth of population and tourism also presents significant land and water-resource challenges, including development on steep slopes and in floodplains, as well as issues pertaining to water conservation and stormwater management. The university campus is located in the watershed of Boone Creek, a tributary to the New River. Stormwater from campus and the dense historic downtown drains into the creek which is culverted along ASU's main access road and daylit through a linear park at the campus entrance. Because water is crucial to all life, but does not respect political boundaries, it offers an excellent focal point for addressing complex adaptive social-ecological systems (Walker & Salt, 2006).

### *The Water Resources Planning Committee*

In February 2007, WRPC–comprised of faculty from six academic departments, a professional engineer from the Office of Design and Construction, and members of three community organizations–was charged by the ASU provost with developing recommendations to manage Boone Creek on campus. In less than two years, WRPC evolved from a "green" campus initiative to a nascent prototype for institutional transformation. The Committee joins people from operational and academic units, involves community organizations and local governments in its work, has high-level administrative support for its recommendations, and is growing in resource allocation and influence despite conflict. The following narrative of WRPC's inception shows how individuals and events converged in unpredictable ways to "embrace emerging opportunities [and] constantly shifting priorities and resources" (Sharp, 2002), inadvertently creating a window of transformative opportunity for sustainability.

Several unrelated events and activities contributed to the window of opportunity that opened to enable WRPC to be established. Early in 2004, Jana Carp's planning studio course on the stabilization and enhancement of the downtown creek catalyzed an ad hoc citizen's committee called the Kraut Creek Committee (KCC) ("Kraut Creek" is the vernacular name for Boone Creek derived from a mid-20th century sauerkraut factory that regularly released its effluent into the stream). Members represent academic, political, environmental, and economic development interests and advocate protecting and enhancing the stream to their separate constituencies. Later that year, hurricanes brought significant flooding to the region and then, in 2005, the municipal government released a study documenting the need to increase its water supply. In 2006, KCC began work on a grant-funded feasibility study—with formal endorsement from town and county governments, ASU, and various local and regional organizations—for improving 1.3 miles of the creek. The university and the local chamber of commerce eventually implemented an off-campus collaborative demonstration project.

Even before these initiatives, ASU science faculty had been conducting teaching laboratories in and along the creek for several years. However, in 2005, three newly arrived science faculty began to develop a cross-disciplinary program of creek-related research, outreach, and educational activities. In 2006, they instrumented the creek and began collecting data. Meanwhile, Kristan Cockerill (an environmental policy analyst) arrived at ASU and started to collaborate with the scientists on grant proposals to expand the creek-monitoring program. She also began to work with a regional nonprofit organization to develop a community water-education program. By late 2006, with almost a year's worth of data showing negative impacts on the creek from runoff-induced thermal pollution and salinity, the physicist on the monitoring team met with the provost to propose that the university proactively manage the creek. The result was WRPC, of which both authors are members.

Through 2007, WRPC focused on responding to the provost's charge to make recommendations regarding creek management. Members discussed creek-remediation concepts and reviewed the upstream-remediation efforts of KCC and the county cooperative extension office. The group decided to expand its scope from a single creek to the broader campus and its watershed. Recommendations in WRPC's report to the provost included adding low-impact development policies to design and construction guidelines, establishing a director of sustainability for campus operations, designating WRPC as the advisory committee to review design and construction plans for water-management impacts, and funding faculty activities. The provost accepted the recommendations without committing to specific implementation plans and offered unspecified financial support.

In developing the report, WRPC undertook a visioning exercise to establish common ground that produced two broad goals: 1) to rehabilitate the stream to be ecologically healthy; and 2) to provide for diverse use of the riparian corridor for scientific, educational, recreational, aesthetic, and property-management purposes. Individual time constraints, as well as different attitudes toward the relevance of "visioning," truncated the exercise and an attempt to generate more detailed objectives from the various disciplinary perspectives failed. However, the group did agree on the immediate need for a demonstration project to signal the general mission of applying available expertise to improve riparian conditions on campus. A biology professor designed an experiment to assess the effects of grass mowing on riparian invertebrate populations. A campus-project manager serving on WRPC facilitated the logistics of this experiment with the grounds crew. As expected, the results (invertebrate population increased when mowing ceased) showed how simple actions with low cost can have large positive impacts. Then, faculty from physics and chemistry, along with the campus-project manager, coordinated a second experiment to test whether permeable pavement could help with thermal regulation of stormwater runoff. Once funding, timing, and location issues were settled between WRPC and the Office of Design and Construction, the experiment was conducted and showed that this approach did not reduce thermal pollution.

In 2008, Cockerill became chair of WRPC. One of the year's two targets–obtaining more funding to help meet the stated goals–was achieved to a degree. The Committee secured a small external grant to develop a workshop about stream health for middle school teachers, linking ASU faculty, KCC members, and cooperative extension personnel with public school teachers. The provost also provided approximately US$50,000 for nonrecurring equipment costs in response to a request for more than US$200,000 for water-monitoring equipment, support for student researchers, and laboratory personnel. The Committee had asked for funding to conduct several years worth of research across multiple disciplines. The provost noted the fiscal reality that it is easier to buy "things" than to buy "people," and therefore all of the equipment requested was funded and none of the personnel.

The WRPC's second target for 2008–increase input on campus-development activities to advocate for stream health–was also met. The Committee's members reviewed plans for a new building and for a creek-rehabilitation project. Both projects received a generally positive appraisal, with some changes indicated. However, water-management measures included in the initial building plans were later removed due to budget limitations. At Cockerill's request, the provost convened a meeting of faculty, staff, and high-level administrators to discuss constraints and opportunities for the new building's water-related features and how WRPC might be better used in campus water-resource decisions. Important project information was shared and the responsible administrator suggested that the committee appoint a representative to the planning committees for new buildings or other campus-development projects. While this gesture represented high-level administrative support for WRPC input, several members perceived service on these committees as additional uncompensated work, limiting the incentive to participate. Cockerill has attended several planning meetings, but this is an ongoing concern for the Committee.

The WRPC is the first faculty-led committee at ASU with diverse institutional and off-campus membership and an official advisory role in campus development. Comparing conditions "before" and "after" WRPC helps gauge its effectiveness. Before, campus-water resources were not considered comprehensively and faculty and community expertise was excluded in designing campus projects with significant water impacts. Now, the Committee's input is welcomed. Before WRPC, there was limited interaction among various disciplines and interests related to campus-water resources. Now, WRPC is a venue to discuss both disciplinary and collaborative approaches to teaching, research, and practical management of water on campus and in the surrounding community.

The Committee is not the formal "change management team" that Sharp (2009) discusses as central to organizing institutional transformation toward sustainability. However, in the short time it has existed, and despite its small size, it has taken positive steps toward its two primary goals of promoting stream remediation and encouraging diverse use. These objectives require engaging faculty, administrators, and the community in addressing campus-water management, and WRPC is gradually strengthening this capability. Providing input to campus building-design plans, promoting rehabilitation projects on and off campus, and continuing to monitor stream conditions all contribute to improved creek health. It is, of course, too early to see definitive ecological results, but integrating WRPC expertise into campus-building projects has widened the field of proposed water-management solutions and initiated a discussion of long-term impacts. For example, the Committee formally made several water-related recommendations including that rainwater catchment and low-impact development technologies be included in the revised campus design and construction manual. Although this document is still under review, indications are that the Committee's proposals will be included in the final draft. In terms of the second goal, WRPC supports access to the creek for diverse uses, promoting it as an asset to be remediated rather than an inconvenience for campus development. The Committee has also raised external funds to use the creek as a teaching "laboratory," as well as a focal point for research.

While these new opportunities for sustainability education, research, and advocacy are prerequisites, the ultimate goal is institutional transformation that addresses ecological, social, and economic concerns in an integrated and habitual fashion. This process includes both material changes on campus and cognitive changes in attitude and vision among decision makers. To achieve this step, stakeholders must recognize the need for change, disclose information, provide resources, and share both power and responsibility in process and outcome. For WRPC, such transformation would mean enabling any member to become fully engaged, with some form of compensation, in all stages of decision making for campus planning, even when that role is not part of his or her primary responsibilities. This development would reflect cognitive change among those with responsibility for campus functions and increase shared information, resources, and power. Transformation would also mean an institutional commitment to implementing sustainable water-management practices when the long-term benefits outweigh the short-term costs, and reinvesting the resulting operational savings in further improvements (Sharp, 2009).

Institutional transformation would also include a consistent working relationship between the university and the town, along with relevant interest groups, to sustainably manage water and other common resources. Because water does not stop at the campus-property line, the university can be a "good neighbor" by planning its water resources in concert with the town's sustainable planning initiatives centered on, for instance, "smart growth" and "green business," not only because of the ecological and economic benefits, but also because the town's development and political influence affects the university as a whole. Moreover, there are likely to be consequences in resisting transformation. Within the North Carolina university system, ASU has been designated as the state's "sustainability campus." For the rhetoric to match the reality, sustainable concepts must become a material reality and a comprehensive priority for policy and behavior. In addition, recent legislative attention to water quality and water supply at federal and state levels makes it likely that water-management practices will become more heavily regulated in the future.

The window-of-opportunity approach that we describe below involves three phases of the transformative process: transformative opportunities, transformative action, and institutional transformation.

These phases involve multiple parties, their particular responses to external and internal pressures, and the parties' willingness to adapt their actions in the process of collaboration. Referring to the WRPC case study previously described, we show how new (transformative) opportunities arose and describe the situational characteristics that allowed unprecedented (transformative) action to emerge. Without recognizing the dimensions of transformative opportunity, successful transformative action is unlikely to occur. As noted above, this case study shows that a diverse set of actors was able to leverage windows of opportunity into transformative action, although institutional transformation involving WRPC has yet to occur. The window-of-opportunity concept offers a way to identify when and where transformation *may* occur; it cannot offer any guarantee that transformation *will* occur. If, however, we improve our ability to identify transformative potential in particular situations, we may realize more opportunities to increase sustainability in higher education and similar settings.

## Leveraging Windows of Opportunity for Transformation

In this section, we discuss indicators that characterize transformative opportunities and describe them at work in the WRPC case. The ideas discussed here were arrived at through an inductive process based on our joint observations. First, we identify four "actor-groups" and demonstrate how they interrelate. We next describe specific capacities characteristic of transformative action: synergy, collaboration, conflict, and flexibility. The subsequent discussion uses diagrams to "freeze" the relationships among actor-groups at three points in time to visually depict the convergence that makes institutional transformation possible, as well as to highlight what occurs once a window of opportunity has opened. We find that transformative opportunities cannot be directed in advance, but that participation in transformative action depends on opportunism and conscientious attention to collaboration to take significant steps toward the institutionalization of sustainable water-resource management.

### *Actor-groups*

Actors are significant to the transformation process because power–as the ability to attract and distribute resources–is differentially distributed among them. Knowledge is also unequally distributed. But while power and resources are often played against each other in a zero-sum game, knowledge can be accumulated and shared to the benefit of all, through increased understanding of institutional functioning. Sharing knowledge and experience is integral to the synergy and collaboration (shared power and resources) required for institutional transformation.

In this section, we describe the four "actor-groups" in our case study. While WRPC is a university committee, members and partners are accountable to diverse constituencies and professions. By primary responsibility, they separate into four groups: university faculty, university administration, local political authorities, and community-based interests. While the identity of specific actor-groups is unique to any case, three *types* of entities are equally important; individuals, informal associations, and institutions each provide characteristic assets and capacities that can mobilize development processes when they are connected and utilized (Kretzmann & McKnight, 1993). As Figure 1 shows, each actor-group may have numerous constituent members. Among the actor-groups, individuals representing associations and institutions actively "bridge" between two or more groups.

Yet coordination among actors that results in an "open window" is not a straightforward process because participants' interests are rarely unitary. Rather than viewing (virtually) perfect alignment of interests as ideal (Figure 2) or complete autonomy as inevitable (Figure 3), we argue that diverse and divergent interests and responsibilities are characteristic of transformative action (Fazey et al. 2007).

An important feature of our window-of-

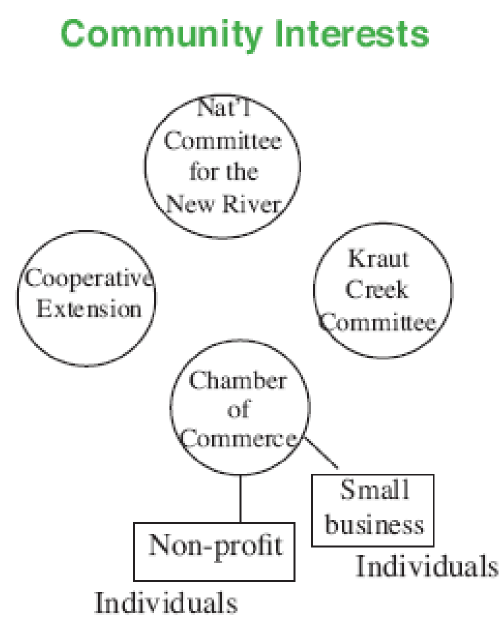


**Figure 1** Each actor-group can be divided into its constituent parts and each part can be further divided into its various elements, eventually arriving at the scale of the individual, who may have membership in multiple actor-groups.

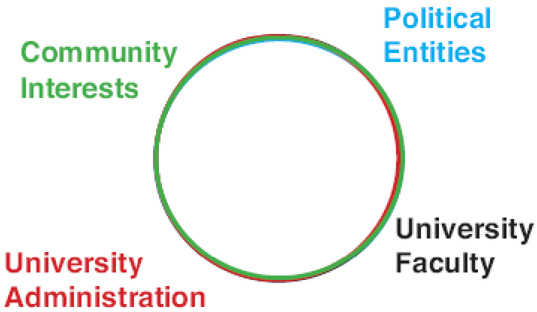


**Figure 2** An unrealistic (but sometimes perceived “ideal”) situation where all interests are perfectly aligned.

opportunity approach is conceptualizing the situation not as a “moving target” with one preferred condition, but as a fluid field of action in which actors have multiple real and potential mutual interests that can be leveraged toward common goals.

The first actor-group, “community interests,” is comprised of individuals and groups associated either with WRPC by professional expertise or an allied community-based organization (or in some cases to both of these networks) and these ties link community institutions, advocacy organizations, and landowner groups. This actor-group includes people who are not necessarily water experts, but who understand the public significance of water problems. In addition to networking, community interests can supply resources, publicity, and educational opportunities, as well as the enthusiasm and appreciation that encourage the difficult work of transformation. Several individual WRPC members are also members of diverse community-interest organizations, including KCC, the National Committee for the New River, and the county cooperative extension office. This integration provides a “bridge” linking various ideas and projects.

Another actor-group, “political interests,” describes people who influence policy and strategies affecting campus-water resources. Beyond the extent of state property in the town, the size and scope of university-related activities influence the surrounding area in terms of housing availability, public services, traffic, economic opportunity, and community character. Water-related projects typically “spill over” into the town, requiring collaboration between campus and community-based political interests. Thus, political actors are significant advocates (and adversaries) in attempts to transform the university’s material conditions. This actor-group includes elected and appointed officials and government staff. While none of the current members of WRPC are elected officials, some do serve on town boards and are key to “bridging” campus and political interests.

“University faculty” is the actor-group whose primary activity occurs on behalf of education, research, and service based at the university. The faculty members who participate in WRPC range in rank from full professor to adjunct instructor, teach students about water resources, conduct and present externally funded scientific and participatory-action research, and support various community-outreach activities. Enabled by their different fields, affiliations, modes of research and pedagogy, and levels of resources, the university faculty use several methods of persuasion to encourage campus transformation.

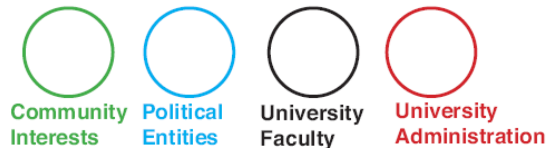


**Figure 3** An unrealistic (but sometimes perceived as inevitable) situation where all interests are autonomous.

In contrast, “university administration” is the actor-group directly accountable for the university’s physical functioning, as well as its institutional leadership. This actor-group spans responsibilities for campus planning, physical plant operation, business affairs and budget, academic mission, fund raising, and policy development and implementation. The WRPC includes a representative from the operational side of campus activities and his participation has been critical to achieving the transformative actions described in this article.

The establishment, increasing responsibility, and growing influence of WRPC reflect a ten-year history of collaboration among individuals and groups. The experience of working both together and separately, using various tools and methods, and communicating with different individuals is complex, multivocal, and divergent. We identify four capacities–synergy, collaboration, conflict, and flexibility–as necessary characteristics of windows of transformative opportunity.

### *Synergy*

Synergy occurs when multiple actor-groups work to realize similar outcomes. Specific events contribute to each actor-group’s focus on an issue and recognition of a common direction with other actor-groups. In the WRPC case, flooding events in 2004, coupled with the 2005 town report on supply limits, focused attention on water throughout the region. Common direction among diverse entities, however, is signified by different forms. The interorganizational, multiscalar context of our case involves, for example, curriculum change, advocacy, scientific experimentation, technological innovation, political negotiation, fundraising and financial investment, citizen involvement, and community festivals. Despite their differences, every actor-group recognizes that addressing water-resource degradation with feasible strategies for change requires coordinated action among entities with diverse expertise and responsibilities.

While the actor-group provides the legitimacy and organization necessary for action, it is individuals who create the relationships that bring groups into contact. As noted, actor-groups in our case included several individuals bridging government, university, and community organizations. They leveraged personal and professional relationships to share information, request consideration, and negotiate agreements. These individual actions collectively sustain the synergy among actor-groups. While such synergy does not minimize conflicts, it can support a network of action in the face of occasional conflict and provide energy and motivation. These circumstances pave the way for collaboration, the second capacity.

### *Collaboration*

Collaboration is demonstrated in sharing knowledge and resources, typically toward achieving a common goal. It is clear to all actor-groups that there is no single disciplinary approach and no overarching authority holds responsibility for managing the creek as a complex adaptive social-ecological system (Walker & Salt, 2006). This common awareness promotes collaboration among actor-groups; sharing knowledge and resources from a variety of different areas of expertise is needed to improve local water-resource management. For example, riparian landowners are aware that scientific research is needed on the efficacy of stream-remediation strategies, while scientists require cooperating landowners to grant access to waterways for gathering data. Engineers need community and political leaders to help identify and support potential projects, while almost anyone developing grant proposals needs to identify matching funds among stakeholders, political entities, and community organizations.

Collaboration on common goals both within and among actor-groups maximizes communication among stakeholders, encourages individual initiatives in relation to an overall project vision, and provides a meaningful experience of collective efficacy (Carp, 2008). The forms of collaboration are varied and the relationships involved are dynamic, with interaction levels ebbing and flowing as issues, projects, relationships, and actors evolve. The WRPC relies on significant cooperation at multiple levels, for example, drafting language that captures multidisciplinarity, collaborating between faculty and a campus-project manager to coordinate the logistics with groundskeepers and contractors for university-based research, and communicating with administrators on facility-planning activities. While collaboration creates opportunities (Wondolleck & Yaffey, 2000; Cockerill et al. 2006), it is not a panacea for addressing complex issues (Roberts & Bradley, 1991; Lubell, 2004). As the next sections address, collaboration does not necessarily reduce conflict and it requires flexibility to be sustained.

### *Conflict*

Although conflict is present in most, if not all, group activities, published case studies often ignore it when reporting "lessons learned" and this is a lost opportunity to fully explore how transformation is likely to become manifest. From our combined decades of initiating collaboration in research, community service, and various workplaces, we have found that stakeholders, especially those that are not involved in professionally facilitated collaborative processes, often consider conflict to be a negative aspect of the process. However, conflict can enable stakeholders to see the various tradeoffs and make decisions with that full knowledge, thus helping to achieve consensus (Putnam, 1986; Dooley et al. 2000). Most decisions made by WRPC required working through conflict or conflict avoidance when members withdrew from discussion. In this particular case, evidence of conflict became manifest in disciplinary incommensurability and divergent perspectives on the history of the group and its purpose.

One source of tension has been evident in members' understanding of the impetus for WRPC. Some faculty criticize the lack of previous attention to the creek and hold that the monitoring program and its data collection were the key to the provost's support. Others note that the success of Carp's studio classes, the role of KCC, and various stakeholder activities from 2004-2006 laid the necessary groundwork. Similarly, members disagree about the validity of diverse research strategies. Evidence of serious study for some members requires the accumulation of quantitative data; for others it is careful inventory and analysis of physical conditions; while still others find community-based design alternatives significant. To varying extents, individuals with these perspectives have created loose "factions" within WRPC and the conflicting frames influence discussions about WRPC goals and specific activities.

In addition to conflict within WRPC, there are tensions among actor-groups. For example, relationships among ASU scientists and KCC reflect a classic science/non-science communication barrier. The KCC needs information to plan future projects, but the scientists provide data, not information (Environmental Law Institute, 2007). So the scientists say that the rehabilitation efforts are happening in a "data vacuum" while KCC finds that the researchers sidestep requests for the results of monitoring activities, such as compiling nonscientific reports for use in discussing municipal stormwater policy. Equipment installation uncovered tensions between the researchers and the town when officials ignored requests for placement information. Also, because it is easier for the administration to purchase equipment than to provide personnel resources, Committee members that required research equipment received internal funding, generating a sense of WRPC as a "pork barrel" for the monitoring team. There is also constant potential for conflict with the university administration. Some faculty who teach water-resources management are put in an awkward position when students identify management deficiencies on campus. As Pittman (2004) reports for many universities, at ASU there is significant rhetoric about being sustainable, but actual decisions are still largely based on short-term economics. At the same time, WRPC's increasing role in advising campus-building efforts risks complicating the design and construction process.

Frustrating meetings and communication gaps coexist with synergy and collaboration, capacities that in turn enable WRPC to surmount the political difficulties of conflict and maintain consistency, viability, dynamism, and creativity. Furthermore, conflicts offer opportunities germane to transformative action, including the self-reflection that enables members of an empowered organization to bridge divisions that constrain conscious interdependence–a key tenet of sustainability (Kaplan, 1996). Working through the conflicted issues has strengthened WRPC's capacity to address difficult challenges. The flexible nature of the group and its operation is another key to its accomplishments.

### *Flexibility*

Flexibility is an essential capacity for leveraging windows of opportunity into transformative action because it enables collaboration to continue, thus extending synergy, despite ongoing conflicts within and among actor-groups. Flexibility holds the possibility for conflict resolution, but it also allows actors and actor-groups to maintain a positive relationship in the presence of unresolved tensions. This situation does not mean that the activity of one group is shaped according to the will of another. Flexibility is evident when actors or actor-groups consider the positions and standpoints of others, even when inconvenient or in opposition, and do not obstruct others' initiatives.

The range of disciplines represented within WRPC results in diverse agendas within the group: scientific monitoring, educating secondary school teachers, and revising the campus design and construction manual. As specific activities develop, various committee members take leading roles and others choose not to participate, but the mix of leaders and nonparticipants is fluid. The lack of direct engagement does not always reflect paucity of support, but is simply a matter of time/energy management for each individual member. A nonparticipant in one activity may well be a leader in another.

Interdisciplinary flexibility also occurs in arguing over terms such as "restoration" and establishing realistic expectations, guidelines, and actions for creek remediation (Bradshaw, 1987; Hilderbrand et al. 2005; Palmer & Allan, 2006; Walter & Merritts, 2008). Early in the development of WRPC there was a particularly forceful discussion about whether "stream restoration" was an appropriate goal for the creek. This was resolved by making clear distinctions between "restoration," "rehabilitation," and "continued degradation," so that Carp, for example, was willing to drop the popular umbrella term "restoration" in favor of the more precise, but less politically attractive, term "rehabilitation" that Cockerill prefers.[1] This conflict was not just about semantics; it enabled the group to define a more distinct goal that is not only shared incidentally by individuals, but is an experience of synergy on which future WRPC actions have been built and to which discipline-specific initiatives can appeal for relevance under the WRPC umbrella.

Concurrently, many WRPC members are personally involved in an intense conflict among departments concerning restructuring the university's general education program. However, they are able to step aside from this intellectual collision to sustain their collaboration specific to stream rehabilitation and water resources. The authors are themselves on different sides of this schism, yet value our synergy to the extent that we are able to collaborate on this article, which we intend to represent both conflict and flexibility at multiple scales from individual to actor-group interactions.

As participant-observers, we have developed a greater awareness of flexibility in relation to activities in which we are personally involved. However, the expansion of WRPC's responsibilities on campus indicates flexibility in other actor-groups, evident as a shared capacity to consider different standpoints. This situation sometimes leads to modifying agendas, actions, language, or expectations, such as the provost's willingness to expand the scope of WRPC to include research funding and review of building

[1] These terms tend to be defined on a case-by-case/publication-by-publication basis. In WRPC, a key point of discussion was that "restoration" can imply a return to a presettlement condition, which is idealistic for urban streams. "Rehabilitation," in contrast, has been used to suggest improving ecological conditions without the sense of an indeterminate historic baseline.

plans. Support for faculty involvement from the Office of Design and Construction surprised several faculty who were familiar with the previous bright line dividing the academic and physical sectors of the campus. The WRPC has also been flexible as collaboration with the administration has proceeded. The group has learned more about the considerable complexities inherent in campus development from the administrative standpoint and thus now recognizes that our influence on development policy will vary accordingly. For example, an initial WRPC recommendation for including pervious sidewalks in plans for a new campus building was retracted as the building designers explained that delivery vehicles must use the sidewalks and current pervious pavement technology is inadequate for the weight loads required.

## Conclusion

In public policy, a window of opportunity enables a problem, solution, and political support to come together. This space allows advocates to promote their intervention and is typically of short duration (Kingdon, 1984). In some policy domains, windows are predictable (e.g., budget cycles). In our use of the concept, windows of transformative opportunity occur organically and cannot be intentionally generated, although it is possible to recognize when one is forming. Our case study suggests that identifiable characteristics include (1) diverse actor-groups with a common interest or goal. These actor-groups are likely to include (2) "bridging" individuals whose overlapping memberships carry the synergy that brings the diverse groups together (3) to collaborate through sharing knowledge and resources. Once in gear, actor-groups (4) use conflict constructively and (5) cultivate flexibility to further common goals.

Figure 4 shows the nature of actor-group relationships and the window of opportunity. While the figure itself necessarily appears as a static image for this publication, in reality each actor-group is dynamic in membership, resources, and foci. The "past" diagram reflects conditions just prior to the inception of WRPC. As these actor-groups changed, conditions were favorable for them to coalesce, opening a window of opportunity as shown in the "present" stage. Here the actor-groups have converged sufficiently to create WRPC as an unprecedented entity on campus: a collaborative committee among faculty, staff, and community interests with formal responsibility to affect campus (and subsequently off campus) water-resource management. Within this window, institutional transformation can occur, but it requires that the actor-groups sustain the synergy of their common goal or goals and continue their collaboration.

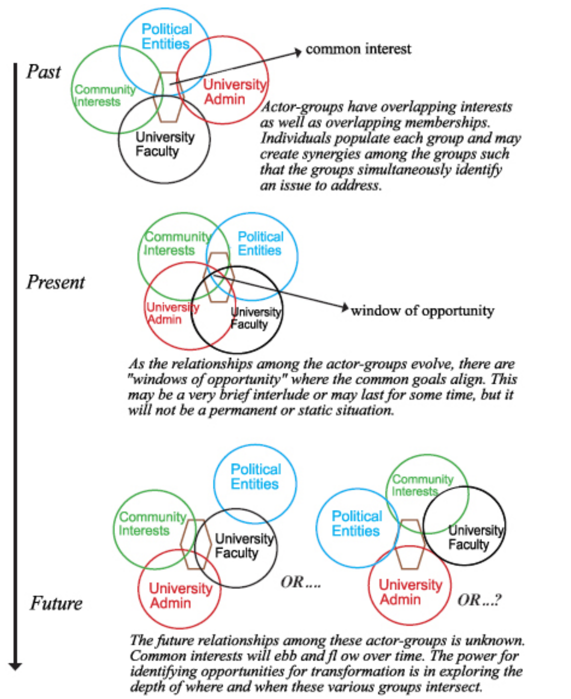


**Figure 4** Using WRPC as an example of the "window-of-opportunity" idea.

The "future" stage shows that continuing relationships among these actor-groups are unknown. Common interests and individual participation will ebb and flow. The power for identifying transformative opportunities is in exploring the characteristics of intersection among these various groups. To the extent that each actor-group transforms within its character to institutionally support sustainable water-resources management, it will provide stability for such management as a common vision. Having a particular window close does not mean that transformation has failed. To the contrary, it may mean that it has succeeded and the conditions that opened the window have changed sufficiently to render that particular window unnecessary. The window needs to be open only long enough to provide room for synergy, collaboration, conflict, and flexibility among actor-groups to achieve Ehrenfeld's (2008) notion that the actions become routine and the norms are embodied: transformation has occurred.

## References

Adomssent, M., Godemann, J., & Michelsen, G. 2007. Editorial. *International Journal of Sustainability in Higher Education* 8(4):462.

Bradshaw, A. 1987. Restoration: an acid test for ecology. In W. Jordan, M. Gilpin, & J. Aber (Eds.), *Restoration Ecology: A Synthetic Approach for Ecological Research*. pp. 23–30. New York: Cambridge University Press.

Calhoun, T. & Cortese, A. 2005. *We Rise to Play a Greater Part: Students, Faculty, Staff, and Community Converge in Search of Leadership from the Top.* 2005 Update in Support of Campus Sustainability Day III. Ann Arbor, MI: Society for College and University Planning. http://www.scup.org/asset/49750 /scup-csd-101705.pdf.

Carp, J. 2008. "Ground-truthing" representations of social space: using Lefebvre's conceptual triad. *Journal of Planning Education and Research* 28(2):129–142.

Cockerill, K., Passell, H., & Tidwell, V. 2006. Cooperative modeling: building bridges between science and the public. *Journal of the American Water Resources Association* 42(2):457–471.

Cortese, A. 2003. The critical role of higher education in creating a sustainable future. *Planning for Higher Education* 31(3):15–22.

Dooley, R., Fryxell, G., & Judge, W. 2000. Belaboring the not-so-obvious: consensus, commitment, and strategy implementation speed and success. *Journal of Management* 26(6):1237–1257.

Ehrenfeld, J. 2008. *Sustainability by Design: A Subversive Strategy for Transforming Our Consumer Culture.* New Haven, CT: Yale University Press.

Environmental Law Institute. 2007. *Lasting Landscapes: Reflections on the Role of Conservation Science in Land Use Planning.* Washington, DC: Environmental Law Institute.

Fazey, I., Fazey J., Fischer, J., Sherren, K., Warren, J., Noss, R., & Dovers, S. 2007. Adaptive capacity and learning to learn as leverage for social-ecological resilience. *Frontiers in Ecology and Environment* 5(7):375–380.

Hilderbrand, R., Watts, A., & Randle, A. 2005. The myths of restoration ecology. *Ecology and Society* 10(1):19.

Kaplan, A. 1996. *The Development Practitioners' Handbook*. Chicago: Pluto Press.

Kingdon, J. 1984. *Agendas, Alternatives, and Public Policies.* New York: Harper Collins.

Kretzmann, J. & McKnight, J. 1993. *Building Communities from the Inside Out: A Path toward Finding and Mobilizing a Community's Assets.* Chicago: ACTA Publications.

Lozano, R. 2006. Incorporation and institutionalization of SD into universities: breaking through barriers to change. *Journal of Cleaner Production* 14(9–11):787–796.

Lubell, M. 2004. Collaborative environmental institutions: all talk and no action? *Journal of Policy Analysis and Management* 23(3):549–573.

Palmer, M. & Allan, J. 2006. Restoring rivers. *Issues in Science and Technology* 23(2):40–48.

Pittman, J. 2004. Living sustainably through higher education: a whole systems design approach to organizational change. In P. Corcoran & A. Wals (Eds.), *Higher Education and the Challenge of Sustainability: Problematics, Promise, and Practice.* pp. 199–211. Dordrecht: Kluwer.

Putnam, L. 1986. Conflict in group decision-making. In R. Hirokawa & M. Poole (Eds.), *Communication and Group Decision-Making*. pp. 175–196. Newbury Park, CA: Sage.

Roberts, N. & Bradley, T. 1991. Stakeholder collaboration and innovation: a study of public policy initiation at the state level. *Journal of Applied Behavioral Science* 27(2):209–227.

Sharp, L. 2002. Green campuses: the road from little victories to systemic transformation. *International Journal of Sustainability in Higher Education* 3(2):128–145.

Sharp, L. 2009. Higher education: the quest for the sustainable campus. *Sustainability: Science, Practice & Policy* 5(1):1–8. http://ejournal.nbii.org/archives/vol5iss1/editorial.sharp.html.

Walker, B. & Salt, D. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, DC: Island Press.

Walter, P. & Merritts, D. 2008. Natural streams and the legacy of water-powered mills. *Science* 319(5861):299–304.

Wondolleck, J. & Yaffee, S. 2000. *Making Collaboration Work: Lessons from Innovation in Natural Resource Management.* Washington, DC: Island Press.

COMMUNITY ESSAY

# Sustainable development of the Amazon forest: a fine line between conservation and exploitation?

**Christopher Reyer**
Potsdam Institute for Climate Impact Research, PO Box 60 12 03, Potsdam 14412 Germany (email: reyer@pik-potsdam.de)

**Author's Personal Statement:**

This essay constitutes a piece of boundary work between science and policy. It illustrates the conflicts, but also the opportunities, that natural resource management encounters in the twenty-first century. I have tried to provide a widely accessible document that argues why a more holistic approach to conservation and natural resource management is imperative. Inspired by the concept of "Integrated Forest Management," I conceived the basics for an "Integrated Sustainable Development" strategy. I have approached the vast topic of "sustainable development in the Amazon" without complicated methodology because I want to present the problem in its inherent complexity and any other manner would largely exceed the length of an essay. A future scientific challenge is to deepen the analysis of why an integrated approach to conservation and ecosystem management is more likely to succeed than a segregative approach. Ultimately, the more political task, however, is to promote dialogue between the manifold and important stakeholder groups in the Amazon to a point where social, ecological, and economic realities are combined and provide a portfolio of sustainable development options.

## The Amazon—A Region at Risk

The Amazon region harbors enormous plant and animal biodiversity that provides substantial regional and global ecosystem services (Constanza et al. 1997; Kier et al. 2005; Grenyer et al. 2006). However, Brazil (where most of the Amazon region is located) faces rapid development likely to degrade the Amazon forest, with worldwide consequences for biodiversity and ecosystem services (Cox et al. 2004; Lenton et al. 2008; Malhi et al. 2009). The reasons for such dramatic ecological changes are manifold: deforestation, fragmentation, fire, macroeconomic pressure, and climate change (see Scholze et al. 2006; Betts et al. 2008; Malhi et al. 2008; Nepstad et al. 2008). Meanwhile, the sustainable development of the Amazon forest is vital to conserve its functions and value for humanity. The estimated worth of nutrient cycling, raw materials provision, erosion control, climate regulation, and other ecological functions is estimated to be US$2,000 per hectare per year, making tropical forests one of the most valuable terrestrial ecosystems (Constanza et al. 1997).

## A Framework of Barriers and Opportunities

*Conservation* is seen here as the preservation of the functioning and diversity of an ecosystem in its current but dynamic state. Although change is an inherent feature of natural systems, the emphasis is on maintaining resistant and resilient systems that contribute to the long-term well being of human societies (Kasperson et al. 1995). Contrary, *exploitation* is any purposeful activity aimed at generating short-term financial benefit while altering ecosystem composition. The successful implementation of conservation and exploitation activities faces different barriers and opportunities, discussed in this essay regarding forest ecosystems in the Amazon. The essay then derives implications for the region's sustainable development.

## Attacked From All Sides—Various Threats to Forest Conservation in the Amazon

The barriers to conservation of the Amazon forest are *institutional*, *socioeconomic*, *economic*, and *ecological*. They are deeply intertwined, but disentangling them into their principal components helps to make clear their respective importance. The *institutional* barriers for the conservation of the Amazon forest ecosystems comprise administrative/legal challenges and irregularities across and along scales, from the organizational to the national policy level. In remote areas unclear land tenure, relative inaccessibility, and resulting ownership conflicts may hinder conservation efforts. Several authors point out the detrimental effects of poor law enforcement, mismanagement, perverse economic incentives, and corruption that set up a framework for uncontrolled and

© 2009 Reyer

arbitrary exploitation of natural resources (Binswanger, 1991; Simmons, 2004; Carr et al. 2005; Bulte et al. 2007). Resulting illegal logging and deforestation challenge conservation efforts and contribute to the Amazon's critical situation (Laurance, 1998).

*Socioeconomic* barriers for conservation in the Amazon are directly related to the population's living conditions. Poverty, demographic pressure from population increase, and global economic forces may drive local people to use the forest irrespective of its conservation status (Geist & Lambin, 2001; Lambin et al. 2001).

*Economic* barriers related to the conservation of the Amazon forest mostly encompass a global undervaluation of ecological services that do not leave valuable economic alternatives other than clearing the forest (Constanza et al. 1997). Currently, the income from the forest and its products (e.g., wood, fruits) is inferior to competing land uses such as farming. Globalized markets and prices increase the economic pressure to convert forests to cropland and the rate of deforestation of the Amazon has been correlated to relevant crop prices in international markets (Morton et al. 2006).

The *ecological* barriers to conservation in the Amazon mostly result from human action. Although constantly progressing and evolving, the lack of knowledge and associated uncertainties regarding ecological processes and biodiversity functioning is inherent to the science of ecology itself (Hooper et al. 2005). Other anthropogenic interventions that create ecological barriers vary in scale and intensity and range from fuel-wood collection to illegal activities such as logging, mining, and poaching to serious overexploitation of the forest and land-use change due to agriculture and plantations. The fragmentation of the forest through infrastructure development (Laurance, 2004) and the propagation of invasive species place additional constraints on successful forest conservation (Asner et al. 2008). Finally, climate change and associated risks and uncertainties (Parrey et al. 2007; Roe & Baker, 2007; Solomon et al. 2007; Eastaugh, 2008) represent a major challenge for biodiversity conservation across the globe, including the Amazon (Lovejoy & Hannah, 2005; Bonan, 2008). The interplay of these barriers results in a change in structure and composition of the forest and in higher fire intensity and frequency threatening an ecosystem where natural fires had been rare (Aragão et al. 2008; Barlow & Peres, 2008; Bush et al. 2008; Phillips et al. 2008). Other ecological processes such as interspecific interactions or mismatching phenological events may build up further ecological barriers.

## Forest Exploitation in the Amazon—Difficulties from Stand to Global Level

Management of a vast forest area such as the Amazon requires a downscaling of measures to the forest-stand level.[1] During management activities, private and public managers may encounter *institutional*, *technical*, *economic*, and *ecological* barriers.

In the Amazon, *institutional* barriers to forest exploitation are mainly related to lack of infrastructure and to corruption (Transparency International, 2008). The application of sound management practices is often hindered by poor quality roads and circumvention of prudent management practices by bribes. *Technical* barriers to forest exploitation in the Amazon are valid for most forested regions of the world. Adequate cost-effective technology for difficult climatic and topographic conditions is lacking and damages from logging are tremendous, causing further forest degradation (Asner et al. 2006). Qualified work forces may exist, but economic pressure and profit maximization hinder their employment. Another important barrier is the interplay of high ecosystem complexity and poor ecological understanding of different species. Thus, silvicultural strategies for these natural forests simplify the forest structure and favor particular species types, such as pioneer species.[2] Remote locations with difficult access also hinder Amazonian forest exploitation.

The main *economic* barrier to managing exploitation of the Amazon forest is the specialization of the timber market into a few commercial timber species. The most prominent example of this selective effect is the quasi-extinction of Mahogany (*Swietenia macrophylla)* due to overexploitation (although numerous other species with similar wood properties exist). The globalized timber market with fluctuating prices and strong pressure for cheap production also undermines sound forest management. Additionally, the comparably lower quality and more difficult processing of timber from natural forests compared to plantation forests (e.g., heterogenous wood properties, large diameters, occurrence of branches) is a further disadvantage for efficacious forest management during economic exploitation. The lack of investment in equipment and staff education for improving forest management is another constraint.

*Ecological* barriers to forest exploitation are mostly due to the Amazon's inherent complexity. While managers seek simplification and control, it is

[1] Forest stand level: A group of trees with a certain set of characteristics that qualifies it as a management unit.

[2] Pioneer species: Species with special functional traits and growth strategies (e.g., light-demanding, long-distance dispersal) that emerge after disturbances. In forest gaps, species that perform the transition from nonforest land to forest land.

impossible to integrate this complex ecosystem. Additionally, climate change, through potentially detrimental effects on infrastructure and accessibility, and because of the large uncertainties it imposes on planning and silviculture, has emerged as a new barrier for managing forest economic exploitation. Although climate change might also create new opportunities, such as enhanced productivity, it is generally assumed to be detrimental for the Amazon forest ecosystem and its processes (Bonan, 2008; Bush et al. 2008; Malhi et al. 2008; Phillips et al. 2008).

## Innovative Options for Future Conservation Activities

Fewer opportunities than barriers exist for the conservation of Amazon forest and the same framework of *institutional*, *socioeconomic*, *economic* and *ecological* elements applies. *Institutional* opportunities act across and along different scales and incorporate administrative and legal opportunities. Large changes in environmental governance have occurred over the last decades. Sovereign nations have ceded parts of their sovereignty to supranational bodies such as the Convention on Biological Diversity and no country plans environmental policy in isolation (Lemos & Agrawal, 2006). This change in environmental governance may be the biggest opportunity for the conservation of forest ecosystems and comes in conjunction with an increasing global awareness of their value. Furthermore, the elaboration of land-use plans and clear land allocation and land-tenure rights foster the conservation of forest ecosystems (Oliveira et al. 2007; Sunderlin et al. 2008). The increasing acceptance and integration of indigenous knowledge and participative planning of conservation and land use with local communities further strengthens conservation efforts and forest protection (Molnar et al. 2004; Chhatre & Agrawal, 2008). Finally, increasing monitoring and planning of conservation activities with clear timeframes, goals, criteria, and indicators, and expanding species inventories for patents of medicinal plants, improve the situation of forest-ecosystem conservation.

The *socioeconomic* opportunities for the conservation of forest ecosystems in the Amazon are primarily related to the barriers that exist in this respect. Hence, better education and a leveling off of population growth, combined with efforts to combat poverty, present valid opportunities. The *economic* opportunities for forest-ecosystem conservation are increasing. Conservation planners have long focused on further valuation of conservation efforts through ecotourism activities. Moreover, payments for environmental services (PES), and especially carbon sequestration in reducing emission from deforestation and degradation (REDD) schemes, provide a wide framework for financing conservation activities and improving local livelihoods (Canadell & Raupach, 2008; Hall, 2008; Jack et al. 2008). More alternative economic benefits emerge from the use of nonwood forest products (NWFPs) such as fruits, gums, resins, and medicinal plants. The availability of large markets is an opportunity; all these “new” products may be traded on a global scale.

The *ecological* opportunities for conservation of Amazon forest ecosystems are limited and consist of increasing scientific knowledge of ecological processes. In already partly destroyed forest ecosystems, restoration ecology fosters the successful implementation of conservation measures (Dobson et al. 1997).

## The Value of Forest Exploitation in the Amazon

The main opportunities for forest exploitation in the Amazon are of a strictly *economic* nature. However, increasing the economic viability of forest exploitation entails other *institutional*, *technical*, and *socioeconomic* opportunities. Although the economic gains of forest exploitation often do not withstand the comparison with competing land-use systems (e.g., cash crops), actually a broad array of products directly result from forest exploitation. The variation in quality and quantity of different product types provides forest managers with the tools for intelligent forest management. Both timber and NWFPs can be produced for certified or uncertified markets. Despite the ecological and socioeconomic importance of specialized NWFPs, fair-trade market schemes, and certification, these cover only niche markets and hence are neither viable nor realistic income alternatives for an entire region such as the Amazon. Forest-certification schemes additionally suffer from being heavily promoted by certain interest groups and excluding other entities more for ideological than rational reasons. Furthermore, these schemes are market-based and consumer choice-driven and hence competing (and often contradictory) certification schemes that are “softer” and “stricter” may confuse consumers and lead to a general distrust of such approaches. Thus, a diverse set of products shelters forest managers from market fluctuations.

Basic principles of sustainable (forest) management are important for the successful implementation of diversified production. Developing and applying management plans and the rejection of “resource mining” production systems are fundamental aspects and increasingly in the minds of policy makers. These economic opportunities, combined with further development of low-impact harvesting techniques (such as reduced impact logging (RIL) for timber or similar considerations for NWFPs) and increasing knowledge on yield capacities and species interactions, improve livelihoods without threatening the forest itself. These considerations align themselves with synergies between forest management and biodiversity conservation, as Putz et al. (2001) point out.

### Synergizing Exploitation and Conservation—A Window for Sustainable Development

To only consider the various barriers and opportunities for conservation and exploitation of the Amazon forest is an oversimplification. However, only by carefully disentangling these intertwined factors is there potential to identify the roots of conflicts and possible synergies. In most cases, it is possible that reduction of a barrier will coincide with an increase in an opportunity. For instance, improving the monitoring of species loss reduces ignorance about the ecological system and may lead to patents for medicinal plants. The latter enables synergies that integrate indigenous knowledge into management/conservation.

The different barriers follow similar directions, albeit the focus differs slightly between conservation and exploitation barriers. For instance, lack of education is a bigger problem for conservation than for exploitation but still touches both processes. Institutional, economic, and, to a lesser extent, ecological barriers are very similar for both conservation and exploitation of forest ecosystems. Hence, they are more related to forests and natural resources in general than to their conservation or exploitation specifically. This is an important finding for solving conflicts among competing interest groups and for improving mutual understanding of these two domains.

Similarly, the opportunities for both forest conservation and forest exploitation in the Amazon are complementary. Further economic valuation of conservation "products"—ecosystem services but also ecosystem raw products—is consistent with efforts to elevate the importance of forests from a matter of local livelihoods to a question of urgency for the global community. Contradictions, such as the globalization of markets, persist between barriers and opportunities for conservation and exploitation of forest ecosystems. This situation may also be due to the huge array of phenomena encapsulated by the term "globalization." The lack of infrastructure and the remoteness of the forests in the Amazon act as barriers to forest exploitation. At the same time, the increasing development of infrastructure is an obstacle to conservation and the remoteness of an area is important for the preservation of a forest. Conventional approaches to conservation therefore oppose infrastructure development and access to forests, whereas sound management for economic exploitation (and also to a certain extent for conservation) requires controlled access. These are concrete contradictions, but in the area of conflict between forest exploitation and forest conservation compromises and trade-offs are a natural part of discussion and planning (Figure 1).

Integrating conservation of forest ecosystems and forest exploitation increases synergies between already overlapping sectors and facilitates the accrual of benefits from incipient opportunities in the Amazon region. Development initiatives that simultaneously aim at, for instance, supporting local livelihoods, promoting biodiversity conservation, and sequestering carbon for climate protection address several challenges outlined earlier. An integrated approach is more resilient, and hence also more likely to benefit from arising opportunities than a segregative approach that ignores particular opportunities. It is, however, uncertain whether an integrated approach addresses a single barrier better than a segregative approach, but it has the potential to better mitigate its impacts. A broader variety of management goals, for example, allows switching the administrative focus if necessary and thus increases the flexibility of managers and diversifies the risk of failure. Furthermore, integrative solutions create greater social utility and help to maintain resilient ecosystems (Scheffer et al. 2000; 2002). Moreover, improving economic security and increasing the local population's well being fosters civil society and helps to overcome institutional barriers such as corruption and poor law enforcement. Such a combination of ecological and social efforts and economic benefits has important implications for sustainable development at a broader scale (Tallis et al. 2008). Applying true

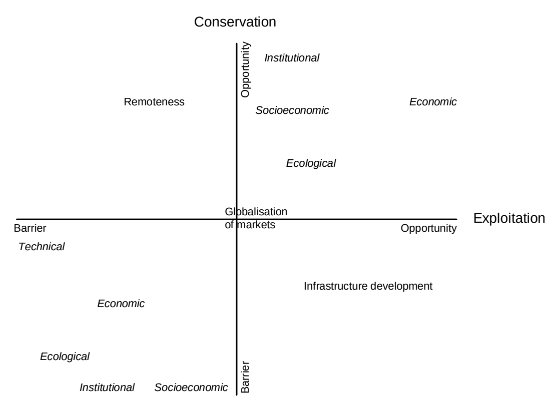


**Figure 1** Synergies and contradictions of barriers and opportunities for exploitation and conservation. The position of the terms indicates their relative importance for exploitation (x-axis) or conservation (y-axis) as barrier or opportunity (*italics*). Only specific contradictions between particular barriers and opportunities are displayed in normal font and further explained in the text.

interdisciplinary knowledge in different sectors and ensuring the integration of multiple social actors is imperative for sustainable development and strengthens decision making and implementation processes to counter the ominous findings (i.e., loss of diversity of life, degradation of ecosystem services) of the Millennium Ecosystem Assessment (MEA, 2005; Ehrlich & Pringle, 2008). Furthermore, at the project level, more holistic and less "conservative" biodiversity conservation projects that focus also on the provision of ecosystem-services benefit from a broader array of funding possibilities and attract greater financial support (Goldman et al. 2008). This financial advantage also indicates that an increasing number of such projects will be successfully implemented. A changing forest paradigm, combined with adjusting perceptions of nature and positive feedback of forestry on poverty reduction, also provides further opportunities for forest conservation (Bengston, 1994; Scherr et al. 2004; Willis & Birks, 2006). In this way, an integrated approach is likely to be more efficient in sustaining the Amazon's ecological functioning and biodiversity as well as the long-term economic benefits from forests.

## Implementing Integrated Conservation and Exploitation—A Case Study from Costa Rica

The biggest challenges to an integrated approach to forest-ecosystem management are political operationalization, practical implementation, and lack of experience. Furthermore, the implementation of such measures is definitely a matter of scale and easier to conceive at the project level than at the regional level. For instance, the "Klinkii—Reforest the Tropics" initiative, an applied research program in Costa Rica (one of the United Nations Framework Convention on Climate Change pilot projects of the "Activities Implemented Jointly" mechanism), is based on the notion of an integrated, multifunctional forest-management system. Although this is a pasture reforestation program not directly dealing with natural forests, it highlights numerous advantages (e.g., participation and training of local farmers, forest management adapted to climate change) of an integrated approach in addressing several of the barriers outlined earlier. Thus, it is conceptually interesting and illustrates what an integrated approach means in practice.

In the Costa Rican project area, pastures on formerly forested lands have been reforested and restored with mixtures of tree species to create diverse forests that are potentially more stable in the face of climate change. The farm forests are managed for both timber production and carbon sequestration by a nonprofit organization, Reforest the Tropics (RTT), and financed by carbon-offset donations from individuals and enterprises in the United States. These forests also provide habitat and food for forest animals and thus help protect local biodiversity. The participating farmers benefit from training on how to implement the complex silvicultural system. Through an initial grant from donors in the United States for the rights to register in their name the carbon captured by the forest, and later from sales of the timber taken out during thinnings, they are released from financial pressure. There are incentives to convert pasture land to forests that produce income because it is only when the forest is profitable that the farmers will manage it sustainably. The goal of RTT is to demonstrate the effectiveness of this strategy and to develop best practices for future projects (Barres, 2009; Reyer et al. 2009).

## Conclusion—Each One, Teach One

Forest conservation and exploitation in the Amazon are constrained by similar barriers, but also share opportunities and important synergies. Actually, both activities are legitimate within a forest ecosystem, an important common property bonding them together. Hence, conservation of forest ecosystems in the Amazon should incorporate more exploitive/management elements and forest exploitation in the Amazon should strive to include more conservation aspects. Such an approach balances conservation and exploitation and enables sustainable development in the Amazon region by respecting economic, social, and ecological realities. Proactive forest conservation, acknowledging the need for development and management to support livelihoods on the one side and less intensive forest exploitation on the other side, resumes the synergies of the various barriers and opportunities for forest exploitation and conservation of the Amazon. The likelihood of addressing the barriers and benefiting from arising opportunities with an integrated approach is higher than with a segregative approach.

## Acknowledgement

I would like to thank Milena Holmgren and Chris Eastaugh for the valuable suggestions on earlier versions of this essay as well as the useful comments of two anonymous reviewers. I am grateful to Herster Barres from Reforest the Tropics for the supporting material on the Klinkii—RTT case study. The *Studienstiftung des deutschen Volkes* and the Erasmus Life Long Learning Programme supported this research. The essay was written while at the Forest Ecology and Management Group at Wageningen University.

## References


Aragão, L., Malhi, Y., Barbier, N., Lima, A., Shimabukuro, Y., Anderson, L., & Saatchi, S. 2008. Interactions between rainfall, deforestation and fires during recent years in the Brazilian Amazon. *Philosophical Transactions of the Royal Society B* 363(1498):1779–1785.

Asner, G., Broadbent, E., Oliveira, P., Keller, M., Knapp, D., & Silva, J. 2006. Condition and fate of logged forests in the Brazilian Amazon. *Proceedings of the National Academy of Science* 103(34):12947–12950.

Asner, G., Hughes, R., Vitousek, P., Knapp, D., Kennedy-Bowdoin, T., Boardman, J., Martin, R., Eastwood, M., & Green, R. 2008. Invasive plants transform the three-dimensional structure of rain forests. *Proceedings of the National Academy of Sciences* 105(11):4519–4523.

Barlow, J. & Peres, C. 2008. Fire-mediated dieback and compositional cascade in an Amazonian forest. *Philosophical Transactions of the Royal Society B* 363(1498):1787–1794.

Barres, H. 2009. Personal Communication. Director, Reforest the Tropics. July 3.

Bengston, D. 1994. Changing forest value and ecosystem management. *Society and Natural Resources* 7(6):515–533.

Betts, R., Malhi, Y., & Roberts, J. 2008. The future of the Amazon: new perspectives from climate, ecosystem and social sciences. *Philosophical Transactions of the Royal Society B* 363(1498):1729–1735.

Binswanger, H. 1991. Brazilian policies that encourage deforestation in the Amazon. *World Development* 19(7):821–829.

Bonan, G. 2008. Forests and climate change: forcings, feedbacks, and the climate benefit of forests. *Science* 320(5882):1444–1449.

Bulte, E., Damania, R., & López, R. 2007. On the gains of committing to inefficiency: corruption, deforestation and low land productivity in Latin Amazon. *Journal of Environmental Economics and Management* 54(3):277–295.

Bush, M., Silman, M., McMichael, C., & Saatchi, S. 2008. Fire, climate change and biodiversity in Amazonia: a Late-Holocene perspective. *Philosophical Transactions of the Royal Society B* 363(1498):1795–1802.

Canadell, J. & Raupach, M. 2008. Managing forests for climate change mitigation. *Science* 320(5882):1456–1457.

Carr, D., Suter, L., & Barbieri, A. 2005. Population dynamics and tropical deforestation: state of the debate and conceptual challenges. *Population and Environment* 27(1):89–113.

Chhatre, A. & Agrawal, A. 2008. Forest commons and local enforcement. *Proceedings of the National Academy of Sciences* 105(36):13286–13291.

Constanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P., & van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387(6630):253–260.

Cox, P., Betts, R., Collins, M., Harris, P., Huntingford, C., & Jones, C. 2004. Amazonian forest dieback under climate-carbon cycle projections for the 21st century. *Theoretical and Applied Climatology* 78(1–3):137–156.

Dobson, A., Bradshaw, A., & Baker, A. 1997. Hopes for the future: restoration ecology and conservation biology. *Science* 277(5325):515–522.

Eastaugh, C. 2008. *Adaptations of Forests to Climate Change: A Multidisciplinary Review*. IUFRO Occasional Paper No. 21. Vienna: International Union of Forest Research Organisations.

Ehrlich, P. & Pringle, R. 2008. Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions. *Proceedings of the National Academy of Sciences* 105(1 Supp):11579–11586.

Geist, H. & Lambin, E. 2001. *What Drives Tropical Deforestation?* Land-Use and Land-Cover Change Report Series No. 4. Louvain: LUCC International Project Office, University of Louvain.

Goldman, R., Tallis, H., Kareiva, P., & Daily, G. 2008. Field evidence that ecosystem service projects support biodiversity and diversify options. *Proceedings of the National Academy of Sciences* 105(27):9445–9448.

Grenyer, R., David, C., Orme, L., Jackson, S., Thomas, G., Davies, R., Davies, T., Jones, K., Olson, V., Ridgely, R., Rasmussen, P., Ding, T., Bennett, P., Blackburn, T., Gaston, K., Gittleman, J., & Owens, P. 2006. Global distribution and conservation of rare and threatened vertebrates. *Nature* 444(7115):93–96.

Hall, A. 2008. Better REDD than dead: paying the people for environmental services in Amazonia. *Philosophical Transactions of the Royal Society B* 363(1498):1925–1932.

Hooper, D., Chapin, F., Ewel, J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J., Lodge, D., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A., Vandermeer, J., & Wardle, D. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* 75(1):3–35.

Jack, B., Kouskya, C., & Simsa, K. 2008. Designing payments for ecosystem services: lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences* 105(28):9465–9470.

Kasperson, J., R. Kasperson, & B. Turner (Eds.). 1995. *Regions at Risk*. Tokyo: United Nations University Press.

Kier, G., Mutke, J., Dinerstein, E., Ricketts, T., Küper, W., Kreft, H., & Barthlott, W. 2005. Global patterns of plant diversity and floristic knowledge. *Journal of Biogeography* 32(7): 1107–1116.

Lambin, E., Turner, B., Geist, H., Agbola, S., Angelsen, A., Bruce, J., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E., Mortimore, M., Ramakrishnan, P., Richards, J., Skanes, H., Steffen, W., Stone, G., Svedin, U., Veldkamp, T., Vogel, C., & Xu, J. 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change* 11(4):261–269.

Laurance, W.1998. A crisis in the making: responses of Amazonian forests to land use and climate change. *Trends in Ecology and Evolution* 13(10):411–415.

Laurance, W. 2004. Forest–climate interactions in fragmented tropical landscapes. *Philosophical Transaction of the Royal Society London B* 359(1443):345–352.

Lemos, M. & Agrawal, A. 2006. Environmental governance. *Annual Review of Environment and Resources* 31:297–325.

Lenton, T., Held, H., Kriegler, E., Hall, J., Lucht, W., Rahmstorf, S., & Schellnhuber, H. 2008. Tipping elements in the earth's climate system. *Proceedings of the National Academy of Sciences* 105(6):1786–1793.

Lovejoy, T. & L. Hannah (Eds.). 2005. *Climate Change and Biodiversity*. New Haven, CT: Yale University Press.

Malhi, Y., Roberts, J., Betts, R., Killeen, T., Li, W., & Nobre, C. 2008. Climate change, deforestation, and the fate of the Amazon. *Science* 319(5860):169–172.

Malhi, Y., Aragão, L., Galbraith, D., Huntingford, C., Fisher, R., Zelazowski, P., Sitch, S., McSweeney, C., & Meir, P. 2009. Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. *Proceedings of the National Academy of Sciences* (in press).

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.

Molnar, A., Scherr, S., & Khare, A. 2004. . Washington, DC: Forest Trends & Ecoagriculture Partners.

Morton, D., DeFries, R., Shimabukuro, Y., Anderson, L., Arai, E., del Bon Espirito-Santo, F., Freitas, R., & Morisette, J. 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proceedings of the National Academy of Sciences* 103(39):14637–14641.

Nepstad, D., Stickler, C., Soares-Filho, B., & Merry, F. 2008. Interactions among Amazon land use, forests and climate: prospects for a near-term forest tipping point. *Philosophical Transactions of the Royal Society B* 363(1498):1737–1746.

Oliveira, P., Asner, G., Knapp, D., Almeyda, A., Galván-Gildemeister, R., Keene, S., Raybin, R., & Smith, R. 2007. Land-use allocation protects the Peruvian Amazon. *Science* 317(5842):1233–1236.

Parry, M., Canziani, O., Palutikof, J., Adger, N., Aggarwal, P., Agrawala, S., Alcamo, J., Allali, A., Anisimov, O., Arnell, N., Boko, M., Carter, T., Casassa, G., Confalonieri, U., Cruz, R., de Alba Alcaraz, E., Easterling, W., Field, C., Fischlin, A., Fitzharris, B., García, C., Harasawa, H., Hennessy, K., Huq, S., Jones, R., Bogataj, L., Karoly, D., Klein, R., Kundzewicz, Z., Lal, M., Lasco, R., Love, G., Lu, X., Magrín, G., Mata, L., Menne, B., Midgley, G., Mimura, N., Mirza, M., Moreno, J., Mortsch, L., Niang-Diop, I., Nicholls, R., Nováky, B., Nurse, L., Nyong, A., Oppenheimer, M., Patwardhan, A., Lankao, P., Rosenzweig, C., Schneider, S., Semenov, S., Smith, J., Stone, J., van Ypersele, J., Vaughan, D., Vogel, C., Wilbanks, T., Wong, P., Wu, S., & Yohe, G. 2007. Technical summary. In M. Parry, O. Canziani, J. Palutikof, P. van der Linden, & C. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. pp. 23–78. New York: Cambridge University Press.

Phillips, O., Lewis, S., Baker, T., Chao, K., & Higuchi, N. 2008. The changing Amazon forest. *Philosophical Transactions of the Royal Society B* 363(1498):1819–1827.

Putz, F., Blate, G., Redford, K., Fimbel, R., & Robinson, J. 2001. Tropical forest management and conservation of biodiversity: an overview. *Conservation Biology* 15(1):7–20.

Reyer, C., Guericke, M., & Ibisch, P. 2009. Climate change mitigation via afforestation, reforestation and deforestation avoidance: and what about adaptation to environmental change? *New Forests* 38(1):15–34

Roe, G. & Baker, M. 2007. Why is climate sensitivity so unpredictable? *Science* 318(5850):629–632.

Scheffer, M., Brock, W., & Westley, F. 2000. Socioeconomic mechanisms preventing optimum use of ecosystem services: an interdisciplinary theoretical analysis. *Ecosystems* 3(5):451–471.

Scheffer, M., Westley, F., Brock, W., & Holmgren, M. 2002. Dynamic interaction of societies and ecosystems: linking theories from ecology, economy and sociology. In L. Gunderson & C. Holling (Eds.), *Panarchy: Understanding Transformations in Human and Natural Systems*. pp. 195–240. Washington, DC: Island Press.

Scherr, S., White, A., & Kaimowitz, D. 2004. *A New Agenda for Forest Conservation and Poverty Reduction: Making Markets Work for Low-Income Producers*. Washington, DC: Forests Trends.

Scholze, M., Knorr, W., Arnell, N., & Prentice, I. 2006. A climate-change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences* 103(35):13116–13120.

Simmons, C. 2004. The political economy of land conflict in the Eastern Brazilian Amazon. *Annals of the Association of American Geographers* 94(1):183–206.

Solomon, S., Qin, D., Manning, M., Alley, R., Berntsen, T., Bindoff, N., Chen, Z., Chidthaisong, A., Gregory, J., Hegerl, G., Heimann, M., Hewitson, B., Hoskins, B., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Somerville, R., Stocker, T., Whetton, P., Wood, R., & Wratt, D. 2007. Technical summary. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. Averyt, M. Tignor, & H. Miller (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. pp. 19–91. New York: Cambridge University Press.

Sunderlin, W., Hatcher, J., & Liddle, M. 2008. *From Exclusion to Ownership? Challenges and Opportunities in Advancing Forest Tenure Reform*. Washington, DC: Rights and Resources Initiative.

Tallis, H., Kareiva P., Marvier, M., & Chang, A. 2008. An ecosystem services framework to support both practical conservation and economic development. *Proceedings of the National Academy of Sciences* 105(28):9457–9464.

Transparency International. 2008. 2008 Corruption Perceptions Index. http://www.transparency.org/news_room/in_focus/2008/cpi2008/cpi_2008_table. March 6, 2009.

Willis, K. & Birks, H. 2006. What is natural? The need for a long-term perspective in biodiversity conservation. *Science* 314(5803):1261–1265.

**Sustainability: Science, Practice, & Policy**
http://ejournal.nbii.org

COMMUNITY ESSAY

# Planning for landscape multifunctionality

**Paul Selman**
Department of Landscape, University of Sheffield, Crookesmoor Building, Conduit Road, Sheffield S10 1FL UK (email: p.selman@shef.ac.uk)

**Author's Personal Statement:**

The term "multifunctional landscapes" has been greeted with suspicion in some quarters as unnecessary jargon for which there are simpler and better-known alternatives, such as multiple use. This community essay explores the meanings associated with landscape multifunctionality and concludes that it is, in fact, a useful term that reflects important new ideas. In particular, it can help to promote landscapes that cross urban-rural divides, are more sustainable, and are planned and implemented in an integrated way.

"Multifunctionality" has become a popular term in landscape design and planning. It has been particularly influential in Europe, where it resonates strongly with the protective and creative measures being promoted through the European Landscape Convention (Council of Europe, 2000). However, while this essay draws principally on European sources, and especially UK practice, it recognizes the term's growing international currency (Bills & Gross, 2005; Cocklin et al. 2006; Robinson, 2006; Lovell & Johnston, 2009a).

A clutch of studies on the UK urban fringe over the last few years has centered on the promotion of multifunctional landscapes (Box 1) (CURE, 2002; Entec UK, 2003; Ove Arup & Partners, 2004; Bartlett School of Planning & LDA Design Exeter, 2004; Gallent et al. 2004; Countryside Agency & Groundwork Trust, 2005). More recently, "green infrastructure" (Benedict & McMahon, 2006) has become a favored vehicle to embed a strategically planned network "designed and managed as a multifunctional resource capable of delivering…ecological services and quality of life benefits…and needed to underpin sustainability" (Natural England, 2008). Similarly, the UK Landscape Institute states that:

> Functions are multiplied and enhanced significantly when the natural environment is planned and managed as an integrated whole; a managed network of green spaces, habitats and places providing benefits which exceed the sum of the individual parts. It is this concept of connectivity and multifunctionality which makes the GI approach such an important part of landscape planning and management (Landscape Institute, 2009).

The term is also entering frontline planning documents. A recent study in Central Scotland argued that: "Multifunctional green networks should be used within the planning process to ensure that greenspace creation and management is spatially targeted to achieve optimum gains for social, environmental and economic development" (SNIFFER, 2008). National policy makers are taking this advice seriously, and such networks are likely to be implemented. At the regional level in England, the North West Green Infrastructure Think Tank (2008) states:

> Functions can co-exist, leading to multi-functionality, and can therefore aid economic, environmental and social objectives through the spatial integration of land uses and activities…Multi-functionality is generally desirable, as it encourages efficient use of land, delivers wider public benefit and builds partnerships of user groups, leading to better stewardship.

More locally, a report on smart growth potential in East Devon (LDA Design, 2009) notes the "opportunity to address the goal of establishing multifunctional landscapes" in urban extensions and new settlements where they serve "to underpin sustainable functioning and 'liveability.'"

However, some critics question whether "multifunctionality" is just another piece of fashionable jargon. This essay interrogates whether or not the term offers a distinct and innovative concept that can advance the sustainable management of urban and rural landscapes. For example, existing terms such as "urban open space" and "green belts" claim the same properties ascribed to green infrastructure, such as containment, recreation, biodiversity, health and ex-

© 2009 Selman

**Box 1** Multiple functions and values of the urban fringe landscape (based on Ove Arup & Partners Ltd., 2004; Gallent et al. 2004; Countryside Agency & Groundwork Trust, 2005).

- "A bridge to the country"–the green infrastructure connecting rural to urban areas
- "A gateway to the town"–features that make a powerful impression of the region
- "A health center"–the health benefits of outdoor recreation
- "A classroom"–hands-on learning such as farm-education centers
- "A recycling center"–i.e., landscaped quarries and landfills
- "A power plant"–to expand, harness and use renewable energies
- "A productive landscape"–i.e., agriculture, forestry
- "A place to live sustainably"–scope for compact, energy-efficient settlements close to work and leisure
- "An engine for regeneration"–increasing the value of often run-down landscapes
- "A nature reserve"–existing ecological assets and scope for creating new ones
- "A heritage resource"–hosting rich and diverse archaeological and historical legacy.
- "A locational function"–occupying a position with potential to reduce travel, reduce food miles, and increase social inclusion

ercise, visual amenity, land-value enhancement, water quality and quantity, heritage, education, and microclimate amelioration. An equally long-standing tradition of the "multiple use" of rural resources promotes combined outputs from land or water under conditions of competition (e.g., Bowes & Krutilla, 1989; Hytönen, 1995). Some of the justifications for multifunctionality refer to the need for land to support more than one activity in response to population growth and social demands. While this may be desirable, it appears very similar to multiple or integrated use. Thus, if landscape multifunctionality is to be a helpful concept, it must offer something that involves more than mere "layering" of different topics such as economics, ecology, culture, history, and aesthetics (Haines-Young & Potschin, 2004). It needs to provide an alternative to predominantly economic concepts such as multiple use and to address more than the efficient coproduction of two or more commodities within a particular land parcel.

The literatures associated with agriculture and landscape give rise to a specific source of confusion. Agricultural multifunctionality is a narrowly defined term with specific policy connotations within the European Union (EU) and the concept is often viewed suspiciously outside the EU as a covert form of protectionism (Schmitz & Moss, 2005). In this context, it refers to "jointness of production" between agriculture, forestry, and other land uses to diversify away from monofunctional food/fiber production (Bohnet et al. 2003; van Huylenbroeck & Durand, 2004; Hagedorn, 2004; Lankoski et al. 2004; Brunstad et al. 2005; Campos et al. 2007). While sharing some common ground with agricultural multifunctionality, landscape multifunctionality addresses a broader social-ecological system and entails an understanding of landscape as something that goes "beyond the view" (Countryside Agency, 2006) and where qualities of placeness and resilience derive from underlying functions rather than surface activities. Even the term "function" is itself a cause of ambiguity. For example, Soini (2001) refers to "qualities" of landscape–the ecological, aesthetic, historical, or symbolic characteristics–and the "value systems" associated with these qualities. Some authors distinguish between structures, functions, and values (c.f. Bergstrom, 1998; Terkenli, 2001). This three-fold division is helpfully summarized by Parris (2004) as:

- *Structures*–natural and human-made environmental features and land-use patterns
- *Functions*–provision of living space, ecosystem operation, soil filtering, water supply, agricultural production
- *Values*–historical, recreational, aesthetic, spiritual, existence, biodiversity, security, agricultural, cultural

The links between these elements are sequential, so that structures supply functions, which in turn may yield values. Brandt & Vejre (2004) have grouped functions into four types–regulation (e.g., climate regulation, nutrient recycling), carrier (e.g., habitation, cultivation), production (e.g., raw materials, genetic and ornamental resources) and information (e.g., aesthetic, educational). Values are often related to the economic, amenity, and security benefits that functions confer on society (Palang et al. 2004).

Apparently similar concepts such as "quality of life capital" and "ecosystem services" cause further confusion over the notion of "functions." The idea of natural capital, long established in the sustainability literature, implies that we should be living only off the "interest" of ecosystem resources rather than depleting the capital stock (Ekins, 2003). Some researchers have thus related landscape sustainability to the continuous enhancement of natural capital (e.g., Haines-Young & Potschin, 2004) and social capital (e.g., Luz, 2000). The Millennium Ecosystem Assessment (MEA) advanced the highly influential concept of ecosystem services that are deemed to comprise:

- Provisioning services such as food, water, timber, and fiber

- Regulating services that affect climate, floods, disease, wastes, and water quality
- Cultural services that deliver recreational, aesthetic, and spiritual values
- Supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005)

This terminology has been enthusiastically adopted into official UK government discourses (DEFRA, 2007).

Although the various terms may appear confounding, they can in actuality be fairly easily reconciled. Both the "capital" and "service" concepts tend to reflect a surface manifestation of underlying systems, while a "function" relates more closely to the dynamic and interactive behavior (functionality) of systems themselves. However, this is not an absolute distinction. For example, while services are explicitly human-centered, this does not imply that they are seen in a narrowly utilitarian way. The MEA argues that long-term human survival and well-being require the promotion of diverse and integrated natural systems, even where this involves economic sacrifice. Some of the scenarios proposed by the MEA (e.g., adapting mosaic) are strikingly similar to multifunctional landscapes (e.g., green infrastructure). Similarly, "capital" analysis should reflect underlying functions even if the procedure does not consider them explicitly (Newson & Chalk, 2004). Thus, multifunctionality is fundamentally ecocentric, having a primary concern for the functioning of earth systems, even though it yields cultural benefits. By contrast, "service" and "capital" perspectives are primarily anthropocentric, focusing on human well-being, even though they rely on underlying functionality. Haines-Young et al. (2006) have helpfully observed that:

- The landscape possesses "biophysical structure or process" (e.g., woodland habitat, net primary productivity)
- This underlying structure/process performs "functions" (e.g., slow passage of water)
- These functions deliver "services" (e.g., flood protection)
- In turn, these "services" have "benefits" or "values" to people (e.g., harvestable products)

Thus, functions have a distinct and critical existence, and planners need to assure their fundamental integrity separately from any benefit they may deliver.

Even if we agree that "functionality" is a worthwhile and distinct concept, this situation still leaves the meaning of "multi" open to question. It seems that the attainment of "multiple" functions entails:

- The pursuit of different goals on the same parcel of land either simultaneously or successively in time
- The integration of different land-use goals at the beginning of a project and constantly revisiting these objectives to accomplish them simultaneously
- Spatial combination of separate land units with different functions (see De Blust & van Olmen, 2000; CURE, 2002; Brandt & Vejre, 2004; Ove Arup & Partners, 2004)

In a multifunctional perspective, land is capable of serving more than one purpose and of fulfilling several needs at the same time. Thus, on the same area of land, key functions–ecological, economic, sociocultural, and aesthetic–can be promoted simultaneously and to mutual benefit. Even so, it would appear that the above principles would not always distinguish between approaches where land-use activities are merely colocated (multiple use) as opposed to genuinely multifunctional.

The literature suggests four distinctive hallmarks of multifunctionality. First, perhaps the most diagnostic theme is that of interactivity as opposed to mere colocation. For example, Gallent et al. (2004) describe multifunctionality in terms of simultaneous spatial integration of functions, especially where these activities lead to beneficial interaction among local economies, the environment, and social objectives. Second, authors typically point to a synergistic effect in which landscape is more than the sum of its parts. Hence, where functional interactivity is positive (and not dysfunctional such as pollution), a more self-sustaining landscape tends to ensue. Much of the visual charm, social vibrancy, and environmental integrity of cultural landscapes derive from a mosaic of land uses that complement each other, generally as a result of fortunate accident. Emerging policy approaches often aim to recapture this kind of serendipitous, dynamic, and self-reinforcing interaction, promoting the reinforcement of "regenerative" landscapes and the rehabilitation of "degenerative" ones. Third, the more recent literature affirms landscape as an integrative system rather than as mere scenery. In this perspective, landscape is defined in terms of its functions, goods, and services (operating in three dimensions) and its time-depth of cultural associations (the fourth dimension).

Finally, multifunctionality shifts the emphasis away from the predominantly rural and positions landscape planning as a practice for the entire land-use matrix. Antrop (2004) suggests a seamless urban-to-rural sequence of landscape–urban center, urban fringe, the rural countryside of the urban network, and the "deep" rural, while Gallent et al. (2006) focus on the undervalued potential of the urban fringe. Arguably, the disconnection between town and country that occurred mainly during the industrial revolution has significantly contributed to our unsustainable lifestyles. Landscape multifunctionality is closely associated with arguments for the "reconnection" of social-ecological systems, so that their integrity and connectivity can be reinstated. For example, following centuries of "taming the flood" and sanitizing biodiversity, society has little collective memory or wisdom about living with nature's caprice, and public authorities are expected to control natural hazards so that urban life is not inconvenienced. Yet there is a growing realization that the limits to control have been reached and that sustainable development will require a relearned relationship between communities and their water/land, based on intelligent care (Iverson Nassauer, 1997). Physical reconnection will entail both horizontal and vertical reintegration of ecological, hydrological, and climatic processes. Thus, ground and surface waters will regain connectivity via sustainable drainage systems (Sharma & Maltby, 2008), encapsulated greenspace will be joined to open countryside through corridor creation (Bryant, 2006), and airsheds will combine with extensive vegetation to provide comfort during a period of climate change (Gill et al. 2007). Multifunctionality is thus most likely to flourish in "connected" landscapes, where physical systems can behave as functional units without excessive human disruption and landscapes possess a spatial and perceptual coherence that facilitates social embedding in the particularities of place.

Writers about multifunctionality also often assume two other conditions. First, they typically prefer landscapes that display heterogeneity (Mander et al. 2007) rather than homogeneity, expressed in terms of visual complexity, ecological opportunity, and physical diversity. Traditionally, landscape planners have focused their attention on the protection of high-quality designated areas and have assumed that the wider matrix is relatively impoverished and not worthy of serious attention. Conversely, multifunctional approaches emphasize opportunities to improve the matrix by increasing spatial heterogeneity through the addition of seminatural landscape elements designed to provide multiple ecosystem services (Lovell & Johnston, 2009b). Second, multifunctionality is often discussed in relation to "landscape scale" and to spatial units based on landscape-scale analyses (Macinnes, 2004; Swanwick, 2004; Hamilton & Selman, 2005; Selman, 2006). This perspective offers the prospect of integrated policy delivery based on landscape units, for example river restoration or promotion of focal species networks. Landscape units may also be related to a sense of place and this may help foster social learning and land care. The integrative potential of the landscape scale can thus assist multifunctional approaches to data collection, policy delivery, and partnership-based coalitions.

Multifunctionality in landscapes is characterized by a high degree of complexity, particularly associated with the properties of simultaneity and interactivity. Not surprisingly, landscape planners have widely resorted to systems models. Knickel & Renting (2000), for example, have explained multifunctional landscapes in terms of substitution and multiplier effects, as well as backward and forward linkages. To resilience theorists, cultural landscapes are social-ecological systems that have a characteristic capacity to regain equilibrium following disturbance (e.g., Walker et al. 2004; Walker & Myers, 2004; Matthews & Selman, 2006). Simpler "soft system" models can be invaluable in understanding the intensity and direction of feedback loops within cultural landscapes (Morris et al. 2006). Landscape "drivers" such as housing development and climate change can be represented as internal and external disturbances as they have forcing effects on system status (e.g., Schneeberger et al. 2007).

While functions and their connecting systems are natural phenomena, we attach human values to ecosystem services, often considering some system responses beneficial and others detrimental. As Naveh (2001) and Haines-Young & Potschin (2004) note, functions are recognized and defined relative to social needs so that multifunctionality emerges from the interaction of ecological systems and human-value systems. Synergy in multifunctional landscapes may therefore lead to self-reinforcing situations that are either "virtuous circles" or "vicious circles," that is, regenerative or degenerative feedback loops (Powell et al. 2002; Selman & Knight, 2006). In the virtuous situation, a landscape is likely to be a sustainable system (Selman, 2008). As is typical with complex dynamic systems, desirable properties are emergent; thus virtuous multifunctionality emerges from a set of conditions difficult for planners to define or orchestrate. We need to accept that hypercomplex environmental systems cannot simply be controlled for human convenience and that sustainable landscapes will involve a degree of risk and "letting go." Thus, simplified monofunctional solutions (e.g., coastal defense works) may be locally appropriate, but increasingly our stewardship will need to accommodate riskier approaches (e.g., managed coastal retreat). Multifunctionality is thus an emergent property that is not easily measured or predicted, but that serendipitously produces sustainable landscape qualities of great value to people.

Several authors have pointed to how land-use planning has reinforced monofunctional land uses by segregating functions into zones (van Mansfelt et al. 1998; Jongman, 2002; Brandt, 2003). In rural areas, monofunctionality has been associated with soil erosion, pollution, energy waste, biodiversity loss, and degradation of services. Not surprisingly, environmentalists and planners often assume that multifunctionality is good and monofunctionality is bad. This duality is simplistic, as economically monofunctional systems may still satisfy certain conditions of sustainable management (Wiggering et al. 2003). However, landscape planners increasingly adopt a general presumption in favor of multifunctionality.

The pursuit of multifunctional solutions will create governance problems–it is clearly much more straightforward to plan for monofunctional outcomes. There is a broad consensus that governance for multifunctionality involves:

- A partnership among public, private, and voluntary sector organizations, as well as individuals and communities (Stockdale & Barker, 2009)
- A transdisciplinary approach that blends the views, skills, and energies of both professional and lay stakeholders (e.g., Tress & Tress, 2001)
- A committed lead organization to enthuse the other partners, but one that is also ready to adopt an exit or succession strategy once a program has become self-sustaining.

A number of recent policy initiatives in the UK demonstrate these qualities to some degree. These efforts include the spatial targeting of public benefit forestry to secure economic and community regeneration (Morris & Urry, 2006; Forestry Commission, 2009); regional-scale habitat networks (Catchpole, 2007; Land Use Consultants, 2008; Whitehead, 2009); and programs of agricultural support measures to promote habitat recovery and catchment-sensitive farming (Natural England, 2008). Ling et al. (2007) have explored how a multifunctional approach to spatial planning–drawing upon historical, ecological, communitarian, economic, and aesthetic functions–could underpin more sustainable regeneration in post-industrial landscapes.

To summarize, I suggest that from a landscape-planning perspective: *multifunctionality provides us with a way of understanding change and delivering joined-up policy at the landscape scale, where its core property of interactivity can be harnessed in ways that produce qualities valued by people*. The key attributes of this perspective are that it:

- Requires not only colocation and coexistence of functions, but also their interactivity to create synergistic effects
- Operates at the landscape scale, including upward and downward linkages between neighborhood, district, and region
- Is a social construct, so that we can reasonably talk about positive (beneficial, virtuous) and negative (detrimental, vicious) interactions, with the former resulting in the accumulation of something valued by humans (e.g., capital, services, and benefits)
- Offers reconnected settings for social learning and collective action so that multifunctional landscapes contain high levels of social and economic entrepreneurship, as well as sustainable environmental systems
- Is a dynamic social-ecological system that is susceptible to catalysis by natural and cultural drivers, some of which are novel (e.g., sustainable energy production, river restoration, carbon-offset plantations) and may create unfamiliar, but potentially cherished new types of cultural landscape
- Implies a coalition-based approach, involving partnerships and joined-up governance, operating over a range of scales, some of which can be related to community attachment and place identity within landscape units

While multifunctionality and green infrastructure have sometimes been seen as unwelcome new jargon, I argue that they do contain important new ideas for sustainable landscape planning (Box 2).

Multifunctionality is thus a fundamental property of sustainable landscape systems. The functional relationships of these systems are never static, and are constantly being deflected by cultural and natural

**Box 2** Are "landscape multifunctionality" and "green infrastructure" genuinely new ideas?

**Multifunctionality–distinctive features**:
- Integration of different land-use goals to promote simultaneous and interactive operation of functions
- Integration of rural, urban, and urban fringe
- Reconnection–social, economic, and environmental
- Synergistic–landscape that is more than the sum of its parts
- Elusive, emergent property
- Operation at a landscape scale–upward and downward linkages between neighborhood, district, and region
- Delivery entails integrated, partnership-based, participatory management and planning, social learning
- Risk-taking to enable serendipitous outcomes

**Green infrastructure–distinctive features**:
- Multifunctional
- Landscape scale
- Includes blue infrastructure (surface and groundwater systems) and airsheds
- Connected–structurally, functionally, socially
- Fundamental to planning and design–not an add-on

drivers, although they are often highly resilient and apparently stable. Landscape functions deliver ecosystem services and sometimes these services may have value to humans. The more that powerful groups of humans value a particular service, the more likely they are to drive a landscape toward monofunctionality. Relatively monofunctional landscapes will require high levels of human input to continue delivering their values and functions and it is likely that a completely monofunctional landscape will cease to be sustainable and will eventually require remediation. Hence, from the point of view of public policy, it will normally be desirable to seek a degree of multifunctionality in all cultural landscapes, and to achieve high levels throughout much of our green infrastructure.

## Acknowledgement

This paper is based on research undertaken for the former Countryside Agency (now part of Natural England) entitled Refining Multifunctionality. I am very grateful for critical comments provided by several Natural England officers, principally Gary Charlton, Dave Solly, Andrew Wharton, and Andrew Gale. Mel Knight of the University of Sheffield provided research assistance on this project. All errors and omissions remain my own.

## References

Antrop, M. 2004. Multifunctionality and values in rural and suburban landscapes. In J. Brandt & H. Vejre (Eds.). *Multifunctional Landscapes Volume 1: Theory, Values and History*. pp. 165–180. Southampton, MA: WIT Press.

Bartlett School of Planning & LDA Design Exeter. 2004. *Vision for a Sustainable, Multi-Functional Rural-Urban Fringe*. Final Report. Cheltenham: Countryside Agency.

Benedict, M. & McMahon, E. 2006. *Green Infrastructure: Linking Landscapes and Communities*. Washington, DC: Island Press.

Bergstrom, J. 1998. *Exploring and Expanding the Landscape Values Terrain*. Faculty Paper Series FS 98-20. Athens, GA: Department of Agricultural and Applied Economics, University of Georgia.

Bills, N. & Gross, D. 2005. Sustaining multifunctional agricultural landscapes: comparing stakeholder perspectives in New York (US) and England (UK). *Land Use Policy* 22(4):313–332.

Bohnet, I., Potter, C., & Simmons, E. 2003. Landscape change in the multifunctional countryside: a biographical analysis of farmer decision-making in the English High Weald. *Landscape Research* 28(4):349–364.

Bowes, M. & Krutilla, J. 1989. *Multiple-Use Management: The Economics of Public Forest Land*. Washington, DC: Resources for the Future.

Brandt, J. 2003. Multifunctional landscapes: perspectives for the future. *Journal of Environmental Sciences-China* 15(2):187–192.

Brandt, J. & Vejre, H. 2004. Multifunctional landscapes: motives, concepts and perceptions. In J. Brandt & H. Vejre (Eds.), *Multifunctional Landscapes Volume 1: Theory, Values and History*. pp. 3–33. Southampton, MA: WIT Press.

Brunstad, R., Gaasland, I., & Vardal, E. 2005. Multifunctionality of agriculture: an inquiry into the complementarity between landscape preservation and food security. *European Review of Agricultural Economics* 32(4):469–488.

Bryant, M. 2006. Urban landscape conservation and the role of ecological greenways at local and metropolitan scales. *Landscape and Urban Planning* 76(1–4):23–44.

Campos, P., Bonnieux, F., Caparros, A., & Paoli, J. 2007. Measuring total sustainable incomes from multifunctional management of Corsican maritime pine and Andalusian cork oak Mediterranean forests. *Journal of Environmental Planning and Management* 50(1):65–85.

Catchpole, R. 2007. *Habitat Networks in England*. June 4–5, Urban Green Conference. University of Salford.

Centre for Urban and Regional Ecology (CURE). 2002. *Sustainable Development in the Countryside Around Towns*. Countryside Agency Working Papers CAX 111 & 112. Cheltenham: Countryside Agency.

Cocklin, C., Dibden, J., & Maunter, N. 2006. From market to multifunctionality? Land stewardship in Australia. *The Geographical Journal* 172(3):197–205.

Council of Europe. 2000. *The European Landscape Convention.* Strasbourg: Council of Europe.

Countryside Agency. 2006. *Landscape: Beyond the View*. Newcastle: Natural England Publications.

Countryside Agency & Groundwork Trust, 2005. *The Countryside In and Around Towns: A Vision for Connecting Town and Country in the Pursuit of Sustainable Development.* Wetherby: Countryside Agency Publications.

de Blust, G. & van Olmen, M. 2000. Monitoring multifunctional terrestrial landscapes: some comments. In J. Brandt, B. Tress, & G. Tress (Eds.), *Multifunctional Landscapes: Interdisciplinary Approaches to Landscape Research and Management* pp. 63–70. Roskilde: Centre for Landscape Research.

Department for Environment, Food, and Rural Affairs (DEFRA). 2007. *Securing a Healthy Natural Environment: An Action Plan for Embedding an Ecosystems Approach*. London: DEFRA.

Ekins, P. 2003. Identifying critical natural capital: conclusions about critical natural capital. *Ecological Economics* 44(2–3):277–292.

Entec UK. 2003. *The Countryside Agency Urban Fringe Action Plans: Their Role, Scope and Mechanisms for Implementation*. Report for Countryside Agency. Cheshire, England: Entec UK Limited.

Forestry Commission. 2009. *Newlands Executive Briefing: Transforming Brownfields into Thriving, Durable and Economically-Viable Natural Environments*. Delamere, Cheshire: Forestry Commission.

Gallent, N., Andersson, J., & Bianconi, M. 2004. *Vision for a Sustainable, Multi-Functional Rural-Urban Fringe*. Cheltenham: Countryside Agency.

Gallent, N., Andersson, J., & Bianconi, M. 2006. *Planning on the Edge: The Context for Planning at the Rural-Urban Fringe*. London: Routledge.

Gill, S., Handley J., Ennos, A., & Pauleit, S. 2007. Adapting cities for climate change: the role of the green infrastructure. *Built Environment* 33(1):97–115.

Hagedorn K. 2004. *Multifunctional Agriculture: An Institutional Interpretation.* 90th EAAE Seminar. October 28–29, Rennes, France. The Hague: European Association of Agricultural Economics.

Haines-Young, R. & Potschin, M. 2004. Valuing and assessing of multifunctional landscapes: an approach based on the Natural Capital Concept. In J. Brandt & H. Vejre (Eds.), *Multifunctional Landscapes Volume 1: Theory, Values and History*. pp. 181–192. Southampton, MA: WIT Press.

Haines-Young, R., Potschin, M., & Cheshire, D. 2006. *Defining and Identifying Environmental Limits for Sustainable Development: A Scoping Study*. Final Full Technical Report to

DEFRA. Nottingham: Centre for Environmental Management, University of Nottingham.

Hamilton, K. & Selman, P. 2005. The "landscape scale" in planning: recent experience of biogeographic planning units in Britain. *Landscape Research* 30(4):549–558.

Hytönen, M. 1995. History, evolution and significance of the multiple-use concept. In M. Hytönen (Ed.), *Multiple-use Forestry in the Nordic Countries*. pp. 43–66. Helsinki: METLA.

Iverson Nassauer, J. 1997. Cultural sustainability: aligning aesthetics and ecology. In J. Iverson Nassauer (Ed.), *Placing Nature: Culture and Landscape Ecology*. pp. 65–84. Washington, DC: Island Press.

Jongman, R. 2002. Landscape planning for biological diversity in Europe. *Landscape Research* 27(2):187–195.

Knickel, K. & Renting, H. 2000. Methodological and conceptual issues in the study of multifunctionality and rural development. *Sociologia Ruralis* 40(4):512–528.

Land Use Consultants. 2008. *Central Scotland Green Network: Defining the Concept*. Edinburgh: Forestry Commission.

Landscape Institute. 2009. *Green Infrastructure: Connected and Multifunctional Landscapes.* Position Statement. London: Landscape Institute.

Lankoski, J., Lichtenberg, E., & Ollikainen, M. 2004. *Performance of Alternative Policies in Addressing Environmental Dimensions of Multifunctionality*. Discussion Paper No. 4. Helsinki: Department of Economics and Management, University of Helsinki.

LDA Design. 2009. Green Infrastructure Study: Exeter Area and East Devon New Growth Point. Exeter: LDA Design Consulting LLP.

Ling, C., Handley, J., & Rodwell, J. 2007 Restructuring the post-industrial landscape: a multifunctional approach. *Landscape Research* 32(3):285–309.

Lovell, S. & Johnston, D. 2009a. Designing landscapes for performance based on emerging principles in landscape ecology. *Ecology and Society* 14(1):44.

Lovell, S. & Johnston, D. 2009b. Creating multifunctional landscapes: how can the field of ecology inform the design of landscape? *Frontiers in Ecology and the Environmen*t 7(4): 212–220.

Luz, F. 2000. Participatory landscape ecology: a basis for acceptance and implementation. *Landscape and Urban Planning* 50(1–3):157–166.

Macinnes, L. 2004. Historic Landscape Characterisation. In K. Bishop & A. Phillips (Eds.), *Countryside Planning: New Approaches to Management and Conservation*. pp. 155–169. London: Earthscan.

Mander, U., Helming, K., & Wiggering, H. 2007. *Multifunctional Land Use: Meeting Future Demands for Landscape Goods and Services*. Berlin: Springer.

Matthews, R. & Selman, P. 2006. Landscape as a focus for integrating human and environmental processes. *Journal of Agricultural Economics* 57(2):199–212.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-being: Health Synthesis*. Washington, DC: Island Press.

Morris, D., Oreszczyn, S., Blackmore, C., Ison, R., & Martin, S. 2006. A systemic approach to scoping of factors influencing more sustainable land use in Herefordshire. *Local Environment* 11(6):683–699.

Morris, J. & Urry, J. 2006. *Growing Places: A Study of Social Change in the National Forest.* Farnham: Forest Research.

Natural England, 2008. *Environmental Stewardship: Higher Level Stewardship Part A—Application Handbook,* 2nd Ed. Newcastle: Natural England Publications.

Naveh, Z. 2001. Ten major premises for a holistic conception of multifunctional landscapes. *Landscape and Urban Planning* 57(3–4):269–284.

Newson, M. & Chalk, L. 2004. Environmental capital: an information core to public participation in strategic and operational decisions–the example of river "Best Practice" projects. *Journal of Environmental Planning and Management* 47(6):899–920.

North West Green Infrastructure Think Tank. 2008. North West Green Infrastructure Guide, Version 1.1. http://www.greeninfrastructurenw.co.uk/html/index.php?page=resources&NorthWestRegion=true. October 30, 2009.

Ove Arup & Partners. 2004. *Countryside Agency Initiatives Operating in the Urban Fringe.* Final Report. Cheltenham: Countryside Agency.

Palang, H., Alumäe, H., Printsman, A., & Sepp, K. 2004. Multifunctionality, landscape values and planning. In J. Brandt & H. Vejre (Eds.), *Multifunctional Landscapes Volume 1: Theory, Values and History*. pp. 219–234. Southampton, MA: WIT Press.

Parris, K. 2004. Measuring changes in agricultural landscapes as a tool for policy makers. In J. Brandt & H. Vejre (Eds.), *Multifunctional Landscapes Volume 1: Theory, Values and History*. pp. 193–218. Southampton, MA: WIT Press.

Powell, J., Selman, P., & Wragg, A. 2002. Protected areas: reinforcing the virtuous circle. *Planning Practice and Research.* 17(3):279–295.

Robinson, G. 2006. Canada's environmental farm plans: transatlantic perspectives on agri-environmental schemes. *The Geographical Journal* 172(3):206–218.

Schmitz, A. & Moss, C. 2005. Multifunctionality in agriculture: externalities and non-traded goods. *International Journal of Agricultural Resources, Governance and Ecology* 6(3–4):327–343.

Schneeberger, N., Bürgi, M., Hersperger, A., & Ewald, K. 2007. Driving forces and rates of landscape change as a promising combination for landscape change research: an application on the northern fringe of the Swiss Alps. *Land Use Policy* 24(2):349–361.

Scotland & Northern Ireland Forum for Environmental Research (SNIFFER). 2008. Urban Networks for People and Biodiversity–Form and Function. Edinburgh: SNIFFER.

Selman, P. 2006. *Planning at the Landscape Scale*. London: Routledge.

Selman, P. 2008. What do we mean by "sustainable landscape"? *Sustainability: Science, Practice, & Policy* 4(2):23–28. http://ejournal.nbii.org/archives/vol4iss2/communityessay.selman.html.

Selman, P. & Knight, M. 2006. On the nature of virtuous change in cultural landscapes: exploring sustainability through qualitative models. Landscape Research 31(3):305–317.

Sharma A. & Maltby, E. 2008. Sustainable Drainage Systems (SUDS): an integrated and joined-up approach to urban drainage. *Environmental Scientist* 17(1):8–13.

Soini K. 2001. Exploring human dimensions of multifunctional landscapes through mapping and map making. *Landscape and Urban Planning* 57(3–4):225–239.

Stockdale, A. & Barker, A. 2009. Sustainability and the multifunctional landscape: an assessment of approaches to planning and management in the Cairngorms National Park. *Land Use Policy* 26(2):479–492.

Swanwick, C. 2004. The assessment of countryside and landscape character in England: an overview. In K. Bishop & A. Phillips (Eds.), *Countryside Planning: New Approaches to Management and Conservation*. pp. 109–124. London: Earthscan.

Terkenli, T. 2001. Towards a theory of the landscape: the Aegean landscape as a cultural image. *Landscape and Urban Planning* 57(3–4):197–208.

Tress, B. & Tress, G. 2001. Capitalising on multiplicity: a transdisciplinary systems approach to landscape research. *Landscape and Urban Planning* 57(3–4):143–157.

van Huylenbroeck, G. & Durand, D. 2004. *Multifunctional Agriculture: A New Paradigm for European Agriculture.* Aldershot: Ashgate.

van Mansvelt J., Stobbelaar D., & Hendriks K. 1998. Comparison of landscape features in organic and conventional farming systems. *Landscape and Urban Planning* 41(3):209–227.

Walker, B., Holling, C., Carpenter, S., & Kinzig, A. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9(2):5.

Walker, B. & Meyers, J. 2004. Thresholds in ecological and social-ecological systems: a developing database. *Ecology and Society* 9(2):3.

Whitehead, I. 2009. *Facilitating Stakeholder Participation in Development of a Forest Habitat Network within the Edinburgh and South-East Scotland Strategic Development Plan Area*. UK International Association for Landscape Ecology Conference. September 1–3, Edinburgh University. UK: IALE-UK.

Wiggering, H., Müller, K., Werner, A., & Helming, K. 2003. The concept of multifunctionality in sustainable land development. In K. Helming & H. Wiggering (Eds.), *Sustainable Development of Multifunctional Landscapes*. pp. 3–18. Berlin: Springer.

**Sustainability: Science, Practice, & Policy**
http://ejournal.nbii.org

BOOK REVIEW PERSPECTIVES

# Peter Dauvergne, *The Shadows of Consumption: Consequences for the Global Environment*

MIT Press, 2008, 328pp, ISBN: 0262042460

**Foye Hatton**

School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ UK (email: f.hatton@uea.ac.uk)

In 1998, David Crocker and Toby Linden claimed that there had never been a greater need for "society-wide deliberation about appropriate consumption." More than a decade on, as throughput of materials increases and the local and global consequences of modern-day consumption become ever more apparent, one can only assume they are still waiting. Peter Dauvergne's latest book, *The Shadows of Consumption*, could be seen as an attempt to trigger that discussion, raising key questions about the environmental and social costs of consumption. Globally, who are the winners and losers with respect to current consumption trends? How and why do consumption patterns evolve as they do? And most importantly, how can environmentalism be transformed and accelerated?

This is a book about the big picture, and Dauvergne, a professor of political science at the University of British Columbia, takes a fresh approach to examining the "environmental consequences of consumption." Rather than focusing upon the "immediate impacts...on local environments and lifestyles," as has often been done before, he aims to step back and explore the "environmental spillovers," the "full resulting *global* patterns of harm"—what he describes as the ecological shadows of consumption.

The book consists of 24 chapters organized into seven sections: an introduction, five case studies (automobiles, leaded gasoline, refrigerators, beef, and harp seals) and a conclusion. The case studies are thoroughly researched, well written, and filled with informative and entertaining anecdotes. They are used to great effect to, as Dauvergne describes it, peel "away some of the layers of complexities of how and why ecological shadows of consumption form, intensify, and fade." These case studies are a joy to read—aside, that is, from the sometimes alarming content, which, for example, reveals that over one third of the world's grain is used to feed livestock rather than people. Ultimately, the case studies illustrate how in an increasingly globalized world, the impacts of consumption are being progressively pushed upon the world's poorest people, most vulnerable ecosystems, and future generations.

The real meat of this text lies, however, in the introductory and concluding sections. The two initial chapters set the scene, primarily establishing that levels of global consumption are increasing year after year. The global population is set to exceed nine billion by 2050, with most of the expansion taking place in the "developing world," where new generations are striving for and embracing "developed world" lifestyles. As such, per capita rates of consumption can be expected to continue to rise. While this may have many benefits, Dauvergne argues that the environmental consequences are dire. Why individuals "choose" to consume as they do is given fairly little attention; it is suggested that "need, habit, belief, desire, [and] fear" all play their parts, although, as Dauvergne rightly asserts, "the global political economy determines the 'options' as well as guides the collective 'choices' of consumers." Globalization, it appears, has led to the negative impacts of consumption being felt further and further from the point of purchase. While this has been accompanied, in part, by advances in global environmental management, ecological costs continue to be exported to the poor and powerless. Change is occurring too incrementally to avoid extreme risks to many of the world's ecosystems and billions of its people. Climate change, biodiversity loss, and chemical proliferation all point toward the need to "map particular shadows of consumption in detail—to learn how they are affecting us and *why* they are advancing or receding."

In the two concluding chapters, Dauvergne explores the notion that the globalization of environmentalism has failed to slow the ecological cost of consumption. This is partly because proposed solutions have often merely reinforced the neoliberal economic order, and partly because "economic globalization is...diminishing the capacity of activists and states to influence the direction, speed, and intensity of the environmental consequences of consumption." Dauvergne argues that processes of environmentalism can, and must, be transformed, and describes

© 2009 Copyright held by author

how a more "balanced consumption" may be encouraged. The "Balanced Consumers" section argues that individuals must embrace "cautious consumption." "Balancing Corporations" outlines the need to discourage corporations from exporting environmental costs and encourages them to embrace a more precautionary principle with regard to new technologies. "Balancing Trade" argues for the need to ensure that "trade and trade agreements do not lower environmental standards." Lastly, "Balancing Financial Flows" calls for international aid that assists poorer nations in blocking ecological shadows and protecting their environments. While Dauvergne argues that "sweeping reforms to the world order" are necessary, after 23 chapters outlining the dire environmental crisis facing the world, the reforms he suggests seem far from sweeping.

The book shies away from the heart of the argument about modern-day consumption patterns: does sustainable consumption require individuals to consume less, or simply to consume more efficiently? For some, the answer to this question is clear. For example, the United Nations Environment Programme (UNEP) states that "sustainable consumption is not about consuming less, it is about consuming differently and consuming efficiently" (Jackson & Michaelis, 2003). Perhaps this cautious position is partly because, "if limitation of throughput is to be combined with eliminating [global] poverty, the implication is that rich countries' throughput should be *radically* reduced" (Lintott, 1998)—clearly an economically unpalatable proposal for the "developed world."

From this perspective, more efficient consumption is the only way forward. As Dauvergne illustrates throughout this book, this is insufficient on its own, since reductions in environmental harm per unit of output are currently more than outweighed by expanding markets—what Røpke (1999) describes as the rebound effect. In the conclusion, however, Dauvergne sets the rebound effect aside, refusing to engage with the prospect that, as unpalatable as it may at first seem, genuine balanced consumption may require dramatically reduced levels of consumption in the "developed world."

While Michaelis (2000) may be correct that "the ethics of modern consumer society seem to be in many ways at odds with the aim of achieving sustainable consumption," the world has without doubt come a long way since the 1992 Rio Earth Summit. At that conference, according to anecdote, consumption was not discussed due to "an informal agreement that the Third World [sic] would not raise...[First World consumption] if reciprocally the First World [sic] did not raise the issue of population control" (Miller, 1995). Many years later people are awakening to the consequences of such shortsightedness. The environmental and social costs of current consumption patterns are ever more evident, the effects of climate change are being felt around the world, financial systems are starting to creak, the correlation between material consumption and human well being is under scrutiny, and many are questioning consumption patterns. Events such as "Buy Nothing Day," based on the principle of consuming less and living more, expand year after year. And while there may not yet be millions of people opting for lives of voluntary simplicity, unless books such as this one are a little bolder in at least acknowledging the need for throughput reduction, it is unlikely that there ever will be. Recognizing the rebound effect is one thing, but more fully exploring its implications is also vital. Jackson & Michaelis (2003) argue that "issues of scale of consumption...involve questioning fundamental assumptions about the way modern society functions" and in turn threaten "a wide range of vested interests." Is not challenging such interests the only real way to ensure "sweeping reforms to the world order?"

This is a fascinating book, written in a refreshingly readable style that breaks free of the ivory tower, and which will appeal to both the general reader and to academics who want to delve into the politics of (un)sustainable consumption. Most importantly, any reader will be left pondering how the world should address its unsustainable consumption patterns. If we are to move toward a "society-wide deliberation about appropriate consumption," this is certainly a step in the right direction.

## About the Author

Foye Hatton is a Lecturer in Environmental Social Science at the University of East Anglia where he teaches modules on environment and society, sustainable consumption, and qualitative methods. His primary research is in the communication of climate change and barriers to sustainable consumption. His most recent research project explored how residents in a low-impact intentional community were rejecting consumer society's value structure, rebuilding social capital, and redefining notions of the good life. Alongside lecturing and research, he campaigns on climate-change issues with the grassroots network Rising Tide UK.

## References

Crocker, D. & Linden, T. (Eds.). 1998. *Ethics of Consumption: The Good Life, Justice, and Global Stewardshi*p. Lanham, MD: Rowman & Littlefield.

Jackson, T. & Michaelis, L. 2003. *Policies for Sustainable Consumption.* London: UK Sustainable Development Commission.

Lintott, J. 1998. Beyond the economics of more: the place of consumption in ecological economics. *Ecological Economics* 25(3):239–248.

Michaelis, L. 2000. *Sustainable Consumption: A Research Agenda. Report for the Commission on Sustainable Consumption.* Oxford: Oxford Centre for the Environment, Ethics & Society.

Miller, D. 1995. Consumption as the vanguard of history: a polemic by way of an introduction. In D. Miller (Ed.), *Acknowledging Consumption: A Review of New Studies.* pp. 1–52. New York: Routledge.

Røpke, I. 1999. The dynamics of willingness to consume. *Ecological Economics* 28(3):399–420.

**Alina M. Szmant**

Department of Biology and Marine Biology and Center for Marine Science, University of North Carolina, Wilmington, 5600 Marvin K. Moss Lane, Wilmington, NC 28409 USA (email: szmanta@uncw.edu)

This book is about how our quest for economic gain, based on the development of more comfortable and affluent lifestyles, is trashing the global environment in ways that many people do not realize, and at distances from home that we might not easily recognize. I consider myself to be environmentally aware, but was shocked to learn that there is approximately one cow for every four human beings on this planet and that Americans now eat on average 175 pounds of beef each year (basically a person's own body weight), compared to 50 pounds a century ago. How about the fact that on the order of 60% of the land in Los Angeles County is made up of roadways and parking lots? These figures reinforce my concerns that the natural world that I value is being consumed to smithereens and irreparably altered by the quest for seemingly endless expansion of human prosperity.

There are hundreds of similar facts in Peter Dauvergne's informative (and alarming) book, *The Shadows of Consumption*. This volume develops five case studies of how new technologies, when taken to their full extent and with the intent of making vast quantities of money, have harmed, and will continue to harm, the natural world. Dauvergne first exposes histories of the global environmental impact of the automobile, leaded gasoline, refrigeration, and industrial beef from applauded (and seemingly innocent) discoveries to activities with disastrous "consequences for the global environment" (the book's subtitle). Each of these first four industries has its own unique set of issues in terms of local and global environmental impacts. Yet several common threads reoccur. However, the fifth, the harp seal-fur industry, while interesting, seems out of place, and I address it separately below.

The four industries or products (automobiles, leaded gas, Freon refrigerants, and beef) were initially developed to meet specific human needs. The first two examples are interrelated through our need for personal mobility. The third case study, a better refrigerant, was introduced to keep food from spoiling and, later on, to keep people cool on hot days. The fourth illustration highlights a way to satisfy our desire to eat more and higher protein food. Dauvergne traces the history of each of these products as they started small and local, with minimal environmental impact, to their global expansion and current scale of harm. In each case, in their early days these innovations improved the lives of a few people, but are now valued and coveted by billions.

Because the early levels of production were small, the resultant environmental impacts were similarly proportioned. But, as should have been expected, growth of these industries to reach as many consumers as possible (and to yield high profits for the inventors and investors) steadily, but surely, began to have serious (and incresingingly global) ecological consequences. Over the century or so that automobiles have been commercially available, we have in many parts of the world plowed the Earth under to build highways and streets. In addition, exhaust from leaded gasoline made the air in urban areas dangerous to breathe and threatened the neurological development of our children (not to mention contributing to global warming from burning oil). The wonderful Freon that made refrigerators safe (earlier units could unexpectedly explode) and kept our food fresh eventually accumulated in the atmosphere to degrade the ozone layer that protects us from harmful ultraviolet rays. In the case of beef, the growing global appetite for hamburgers and steaks is causing the destruction of large tracts of tropical rainforests at alarming rates to graze cattle and raise fodder for cheap production. Furthermore, cattle release huge amounts of methane that rivals the greenhouse effects of automotive carbon dioxide. Deforestation for cattle farming and other agriculture, energy costs to manufacture fertilizers, as well as the burning of fossil fuels for transportation of the fodder and beef products, are among the major sources of greenhouse gases causing our climate to warm at a distressing rate.

Regarding leaded gasoline and Freon, scientific evidence for the harmful effects of these chemicals eventually became public knowledge and civic pressure lead to their banning in the United States and Europe, but only slowly (and still not completely) in less developed countries. I was alarmed to learn how early in the history of these products scientists recognized their harmful nature and how diligently the corporations involved in their production worked to hide the emerging facts. We are living through a similar crisis with respect to global warming because activities that we are reticent to stop are profitable for business (and ease daily life for consumers). One of the common threads for the leaded gasoline and Freon chapters is how corporations, forced to stop production in the developed world, moved manufacturing and sales to less developed countries with poor capacity to enforce meaningful environmental regulations. In the case of automobiles, as safety regulations and concern for environmental impacts increased in the affluent nations, manufacturers again redoubled their efforts to profit from sales in the developing world. Activities profitable in wealthy countries are having severe environmental consequences elsewhere.

In the above four cases, the global environmental consequences have increased hand-in-hand with an expanding population and an increasing standard of living in developing nations, most notably China and India. In chapter after chapter, Dauvergne stresses how the severity of consumerism's environmental consequences has escalated as large multinational companies enlarge their consumer bases (and profits) by broadening their operations in poor countries. And here is where I find fault in Dauvergne's treatment: Why does he avoid tackling head on the importance of controlling human-population growth? The message is subtlety embedded in each of his stories, but never highlighted as a *root cause* of global environmental deterioration.

Dauvergne seems to have held back from explicitly criticizing the interrelationships that link human population size, consumerism, and environmental impact. This is basically the IPAT equation [Impact = Population x Affluence x Technology) introduced by Paul Ehrlich & John Holdren (1971). Our society's inability to deal outright with the issue of human-population control is a sure ticket to our own doom. Dauvergne establishes a framework where he could have easily used to emphasize that the combination of consumption patterns and consumer numbers mandates action. But Dauvergne never brings the message home; instead he emphasizes efforts to increase the recyclability of major products (e.g., cars and refrigerators) and discusses how better land management could reduce adverse effects. He simultaneously admits that these efforts will be futile to combat the negative impacts of widespread automobile use, refrigerator ownership, and increased beef consumption in China and India. In my opinion, even enlightened conservationists and governments are damning our future by their inability—or unwillingness—to explicitly and forcefully deal with birth rates and family size. Chinese government officials have been condemned for coercive population control, but I applaud their brave and unpopular foresight regarding the consequences if human population is not controlled. Unfortunately, it is all too common to avoid bringing up the need to control human-population growth.

So how do we increase concern about the global consequences of too many people wanting too much "stuff"? The general public in developed countries is unconcerned with the growing environmental consequences of modern conveniences that have embedded into our daily lives. In the developed world, people live in artificial dwellings surrounded by human-made contraptions ostensibly designed to make our lives easier, healthier, and more fun, and to increase our productivity. This is what we call "progress." By contrast, in developing nations, people either want to achieve the lifestyles of their developed counterparts or are simply struggling to survive at any and all cost. The problem for the global environment is that there are now over 6.8 billion people on Earth, all striving for this modern, "stuff-rich" standard of living. So how do we shock everyday developed-country citizens into ecological awareness to where they are willing to change their consumption?

The last of Dauvergne's five case studies is the harp seal-fur industry. I do not understand his rational for choosing this example instead of cigarettes, pharmaceuticals, minor appliances, air travel, plastics, electricity, tourism, or any number of other products or services that we now count on to support our daily modern lives. Any of the latter has much broader environmental impacts because of the small number of hunters and the specific nature of the hunt. I am a strong supporter of animal rights and do not buy products tested on animals. I have migrated to a mostly vegetarian diet over the past decade as I became aware of the cruelty of industrial agriculture. I abhor the atrocities of this particular hunt and email my Canadian friends to complain about it each spring. Dauvergne's thorough and detailed history of this pursuit from its early days during the 1700s is interesting from a cultural perspective and angered me when I learned that the Canadian government had only recently revived this defunct industry to create jobs. The only common thread with the earlier chapters is the export of the product to developing countries with different cultural values (i.e. China and India) since the sale of the furs is banned in the United States and Europe. I would have thought that taking on a different industry, such as plastics or shopping malls, would have had greater impact on raising the environmental awareness of mostly Western readers.

In summary, this easy-to-read book is filled with examples about how contemporary lifestyles are damaging our planet. The pursuit of corporate, national, and individual profits, along with our tendency to strive for improvements in our material standard of living and the fact that there are just too many of us, are driving the impending environmental catastrophe. In his book *Collapse*, Jared Diamond discusses societies that succeeded by changing course once they realized the consequences of their lifestyles. However, most of that book is filled with examples of societies that failed because people did not recognize the environmental consequences of their actions. Another recent volume, *Hot, Flat and Crowded* by Thomas Friedman, pulls together additional perspectives on how increasing global population, together with global trade, is leading to environmental ruin. Both of these books try to end on an optimistic note, giving hope that we can change our collective behaviors in time. However, watching how we deal with the human-population issue and the present global economic crisis—which is basically the result of overconsumption (and too much debt) at many levels, corporate greed, and government *laissez faire*—does not give me confidence that we know how to rise to such challenges. If buying more stuff is the only way to "get our economies growing again," we will die buried in the consequences of our consumption. We need a new global social ethic and a new economic theory that is not based on consumption growth.

### About the Author

Alina M. Szmant is Professor of Marine Biology in the Center for Marine Science at the University of North Carolina, Wilmington. She is a coral-reef ecologist and coral physiologist whose current research focuses on the effects of climate change (ocean warming and ocean acidification) on the early life stages of Caribbean reef corals. Alina has also been collaborating with molecular geneticists to help develop genomics tools to study how elevated seawater temperatures disrupt embryonic development. Recent articles are being published in *Global Change Biology*, *Coral Reefs*, and *Biological Bulletin*. She is a member of the SSPP editorial board.

### References

Ehrlich, P. & Holdren, J. 1971. Impact of population growth. *Science* 171(3977):1212–1217.

## *Rejoinder from the author*

**Peter Dauvergne**

Liu Institute for Global Issues, University of British Columbia, Vancouver, British Columbia, V6T 1Z2 Canada (email: peter.dauvergne@ubc.ca)

I am indebted to Alina Szmant and Foye Hatton for their astute reviews. It is heartening to see both respond so positively to the core ideas, arguments, and writing style of *The Shadows of Consumption*. I see this book as one step in a long journey of learning about the "problem of consumption" that began as a boy jigging for cod off the coast of Nova Scotia. Responding to such perceptive feedback is a real privilege: an opportunity to refine my thinking and develop new questions.

Szmant quite rightly prods me to justify further my choice of Canadian seal products as one of my case histories from the hundreds of thousands of possibilities. Why not plastics cigarettes, tourism, or air travel, she asks. Such industries, after all, are more comparable to the book's other cases—and would do more to raise "the environmental awareness of mostly Western readers." One reason, I should admit, was a curiosity arising from childhood memories of local fishermen heading off each spring into a storm of protestors demanding an end to the "brutal" and "inhumane" hunt for "baby" harp seals. But I primarily chose sealing *because* it is at the periphery of the world economy and *because* seal furs are a luxury item with relatively easy substitutability. I wanted to explore how the consumption of products with small political economies and many substitutes might, or might not, differ from core products. I saw this as essential for a more comprehensive understanding of the forces driving global consumption patterns given that together thousands of such products combine into big global consequences.

I accept Szmant's point, however, that except for the analysis of sealskin exports to Russia and China since the mid-1990s, the history of consuming seal products does not weave as easily as the other cases into the book's common themes around the role of multinational companies, powerful states, and growing global markets. Still, I do think the history of consuming harp seals opens many new insights into how and why global consumption patterns shift. For one, the analysis of the global campaign to close Canada's seal hunt—with success in the 1980s and failure since the mid-1990s—helps reveal globalization's contradictory consequences for activists' emotional and moral appeals to consumers. No doubt the globalization of communication technologies is allowing more activists from more places to reach more people faster. Yet, as the recent emergence of markets in China and Russia for seal products shows, at the same time the globalization of markets is making it harder and harder for increasingly diverse activists to outflank corporations and government agencies and reach enough people across enough cultures to achieve lasting change.

Szmant wonders further, given my analysis and conclusions, why I do not tackle "head on the importance of controlling human-population growth" as a "*root cause* of global environmental deterioration." Rising population, as she notes the book reveals, is aggravating many consequences of consumption for just about every consumer product. Still, I intentionally kept my spotlight on rising consumption, not rising population, as the root cause of the global environmental crisis. For me, the crises of climate change and deforestation and collapsing fish stocks are symptoms of a consumption crisis, not a "population bomb." Pointing to rising consumption as the root cause raises the stakes, challenging something far more insidious and difficult to stop than rising populations.

Unlike population growth, consumption is embedded in societies as innately good, as something to increase for community welfare, to grow economies out of recessions and into prosperity. Few national leaders, for example, are calling for measures and policies to increase birth rates, and some, as in China, are imposing controls to reduce them. Yet, everywhere, leaders are working hard to increase consumption—from incentives to trade-in big ticket items like automobiles to speeches that tell citizens it is patriotic to borrow and buy. So strong is the faith in the value of rising consumption that almost no one in power ever calls for less. In such contexts, pointing to population growth as the cause of environmental problems can even deflect attention from consumption so that, for instance, the "solution" to freshwater shortages in the United States becomes closing borders to migrants rather than reducing industrial and personal consumption of freshwater (*not*, I should stress, what Szmant argues, or even hints at).

Furthermore, reducing population will do little to resolve the global environmental crisis if current consumption patterns deepen. Granted, reducing the global population to 4 billion people—or more drastically 1 billion people—would make this task easier. Yet only a truly horrifying pandemic will achieve this end. Realistically, even a global one-child policy, which as China shows would surely cause family pain and social distortions, would only bring the world population down slightly. And, as a glance at today's China shows, there is no guarantee that governments will not ramp up production to grow economies of higher-consuming smaller families. Demographic trends suggest the era of exponential population growth is now set to end around the middle of this century. For me, the key is to start *now* to find ways to ensure that these 9-10 billion people are *consuming smarter* and *consuming less* natural capital as a population than today's 6.8 billion consumers. Such a world will then need to ensure economic and social stability as the global population inevitably declines as people with more opportunities choose to have fewer children.

To address the problem of consumption Szmant persuasively calls for a "new global social ethic" and a "new economic theory that is not based on our consumption growth." Otherwise, as she succinctly says, "we will die buried in the consequences of our consumption." I could not agree more. I conclude *The Shadows of Consumption* with the purpose of beginning a conversation about how to move toward more balanced consumption, both for individuals and the global economy. I note the value of individuals changing lifestyles: reducing, reusing, recycling. But I stress the vital importance of going beyond the individual to transform and control the systemic drivers of current consumption patterns, such as multinational corporations, trade, investment, technology, and globalization. As Hatton correctly observes, however, such reforms "seem far from sweeping." I do not call for a revolution to overthrow capitalism, and I still see considerable value in transforming current institutions.

Nevertheless, getting institutions to change fundamentally will require sweeping away many of the old assumptions and goals underpinning them. Doing so, however, is far from easy, and, after finishing *The Shadows of Consumption*, I was personally still unsure where to start.

As the book was in production at MIT Press, I decided the logical place to begin was my own institution. Universities and colleges are especially well suited to act as sustainability leaders, innovating, researching, and advancing our understanding of effective ways to reduce consumption and increase wellbeing. The underlying motives for universities are primarily students and research: money of course matters, but not to the same degree as with most of the other institutions driving consumption growth (universities are also, of course, a big reason for the problem of consumption). Thus, transforming a university into a model of sustainability—from teaching to research to operations—has the potential to influence the actions of individual consumers as well as to cascade change through the global system by demonstrating best institutional practices and educating future leaders.

In July 2008, I joined a team to try to do just that at the University of British Columbia (UBC), working full time as Senior Advisor to the President. Many colleagues were surprised that I was willing to step away from the joys of teaching and writing. However, this decision arose directly from my conclusions in *The Shadows of Consumption*. If I was not willing to help transform my own institution, how could I ask others to do so for more intransigent institutions, such as multinational corporations and trade regimes? Very few academics can say their time in central administration was inspiring. Yet in my case, although our committees have hit—and I'm sure will continue to hit—many rocky shoals of politics and cynicism, we were able to place sustainability at the centre of UBC's new strategic vision.

Our plan, with the admittedly stuffy title of "Sustainability Academic Strategy," rests on three interrelated reforms for teaching and learning, research and partnerships, and operations and administration. To bring these together, UBC will pursue two pathways. The first will develop the university as a "living laboratory," integrating students and academics into efforts to research and *change* our operations. So, for example, among our many goals is to move quickly toward a net positive energy and water campus, where UBC is "producing more energy onsite than is consumed and returning water to the municipal system cleaner than when it was removed" (18 August 2009 draft, at http://www.sas.ubc.ca). The second will see UBC aim to be an "agent of change in the community," where it works closely with and learns from other communities to model best practices. One example, among many, is to "work with key suppliers to build lifecycle-based sustainability targets and tracking mechanisms into all major contracts" (18 August 2009 draft, at http://www.sas.ubc.ca).

Alone, such changes cannot end the crisis of consumption. Both Szmant and Hatton emphasize this point. Yet, as the examples in *The Shadows of Consumption* repeatedly show, such changes can mitigate some of the environmental consequences, especially when, as Hatton correctly stresses, one of the primary goals is to *reduce* total consumption, and not just decrease the harm per unit of output. Hatton is right: reducing consumption and getting to global sustainability will certainly take much bolder steps than just transforming a university here and there; but, at least it is a place to start acting collectively for us academic folk who are most comfortable sitting alone at a desk, pondering.

## About the Author

Peter Dauvergne is Professor of Political Science, Canada Research Chair in Global Environmental Politics, and Director of the Liu Institute at the University of British Columbia. He has also served as Associate Dean in the Faculty of Arts (2006-08) and Senior Advisor to the President (2008-09). In addition, he is the founding and past editor (2001-2008) of the journal *Global Environmental Politics*. His research focuses on the politics of global environmental change, including current projects on sustainable consumption and corporate social responsibility. *The Shadows of Consumption* won the Society of Human Ecology's 2009 Gerald L. Young Award for the best book authored in 2008 in the field.